

Alternative modes of transportation and BART

A proposal to integrate competing transportation systems in the San Francisco Bay Area, California

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Abstract

This study analyses the impact of alternative modes of transportation such as Caltrain, Uber, carpool apps and other significant transport modes on Bay Area Rapid Transit (BART) ridership in the San Francisco Bay Area. BART is a subway service in San Francisco and parts of Oakland and Berkeley while Caltrain services the Contra Costa County, Alameda County, and San Mateo County. These are the two major public transit providers in the giant tech regions of Silicon Valley. According to BART ridership reports, there has been a gradual decline in the number of riders in the years between 2014 and 2018 (BART, 2018)¹.

There has also been a significant increase in the usage of rideshare and carpooling apps in the Bay Area. This study shall do quantitative and qualitative research on ridership numbers, pricing, and time taken for the selected routes for the different modes of transportation including BART. The results are compared for understanding the preference patterns of commuters of these transport options in the Bay Area. The analysis will aid in providing strategies and recommendations for an integrated system among the existing alternative modes mentioned for better public transit facilitation for the people of the Bay Area.

Keywords: San Francisco Bay Area, BART, Public Transportation, Integrated Transit

¹ BART. (2019, January). A History of BART: The Concept is Born | bart.gov. Retrieved February 17, 2019, from <https://www.bart.gov/about/history>

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Chapter 1. Background

On Aug 20th, 2018 the KQED News reported that BART's weekday ridership had fallen, declining 1.9 percent to about 415,000 passengers a day compared to the steady increase of 2%-5% over the previous three years in a row (Veltan, 2018)². Before 2016, the ridership of BART had been increasing steadily every year according to the reports of vital signs that are created by Metropolitan Transportation Commission (MTC) which is a "transportation planning, financing and coordinating agency for the nine-county San Francisco Bay Area"(MTC, 2018.)³. It is mentioned on their website that "On a per-capita basis, transit use is well below the levels of the early 1990s. The average resident boarded transit 79 times per year in 1991, while in 2016, this had fallen to 70 trips per year - an 11 percent decline over 25 years."(MTC, 2018) In parallel, there was a significant increase in the use of rideshare services like Lyft and Uber. According to media producer and analyst, Kevin Truong, the number of rides on these types of services increased to almost five times in 2016 to what it was initially in the year 2014(Truong, 2016)⁴. This thesis focuses on the reasons for the emergence of other alternative modes of transportation in the San Francisco Bay Area over BART in the years between 2015 and 2018. This section briefly summarizes the evolution of BART until 2015 and offers a brief description of other alternative modes of transport that are the major competitors for BART.

² Veltan, C. (2018, August 20). *BART Looks for Solutions After Another Steep Drop in Weekend Ridership*. Retrieved from <https://www.kqed.org/news/11687848/bart-looks-for-solutions-after-another-steep-drop-in-weekend-ridership>

³ MTC. (n.d.). *How much are Bay Area residents relying on public transportation?* Retrieved from <http://www.vitalsigns.mtc.ca.gov/transit-ridership>

⁴ Kevin Truong. (2016). *Uber, Lyft poach passengers, cash away from BART's SFO line* [Transportation Report]. Retrieved from <https://www.bizjournals.com/sanfrancisco/news/2016/12/06/uber-lyft-bart-sfo.html>

S. No	Service	First Year of Service
1	Caltrain	1904
2	BART	1972
3	Uber	2009
4	Lyft	2012
5	Scoop	2014
6	Waze Carpool	2016

Table 1 This table shows the starting year of when different transits have begun their service in the Bay Area including BART mentioned in this study.



Figure 1 Photo taken in one of the BART cars on April 15th, 2019 during the peak hours.

1.1 Bay Area Rapid Transit and its evolution

According to BART's official website, the drive to build BART had started between the business as well as civic leaders on both sides of the San Francisco Bay area because of the heavy post-war migration and the increasing automobile usage that clogged the bridges spanning the bay (BART, 2019c)⁵. This was when the underwater tube between San Francisco and Oakland was planned due

⁵ BART. (2019, January). A History of BART: The Concept is Born | bart.gov. Retrieved February 17, 2019, from <https://www.bart.gov/about/history>

to predicted congestion on the Bay Bridge by the board of officials (BART, 2019c). In 1951, the 26-member San Francisco Bay Area Rapid Transit Commission was created by State Legislature, comprised of a representative from each of the nine counties which touch the Bay. The commission was tasked with creating a plan for future development as there was none before this initiative which was adopted by the Association of Bay Area Governments (ABAG) a decade later (BART, 2019c).

The Commission stated that “If the Bay Area is to be preserved as a fine place to live and work, a regional rapid transit system is essential to prevent total dependence on automobiles and freeways” (BART, 2019c). Therefore, in 1957, the Legislature formed the San Francisco Bay Area Rapid Transit District, comprising the five counties of Alameda, Contra Costa, San Francisco, and San Mateo. Unfortunately, this district designation meant that the counties had to pay more taxes.

Although the engineering and planning of BART were seemingly very successful during 1961, due to the high costs of the new system and existing Southern Pacific commuter trains, San Mateo withdrew from the BART district in December 1961. Subsequently, even Marin County withdrew itself from the BART district as along with tax issues; it also feared the feasibility of carrying trains across the Golden Gate Bridge (BART, 2019c).

Thus, the five-county plan was revised to a three-county plan emphasizing rapid transit between San Francisco and the East Bay cities and suburbs of Contra Costa and Alameda counties. The ‘composite report’ of the plan was approved by the supervisors of the three counties in 1962 and was placed on the ballot for the general election (BART, 2019c)⁶. The plan required at least 60 percent of the votes in favor of the vision to proceed. It was passed with 61.2% of the votes (BART,

⁶ BART. (2019, January). A History of BART: The Concept is Born | bart.gov. Retrieved February 17, 2019, from <https://www.bart.gov/about/history>

2019c). At that time, this “would be the largest single public works project ever undertaken in the U.S. by the local citizenry” (BART, 2019c). Table 2 shows the cost distribution in various parts of the project.

Price Estimation for initial proposal of BART		
S.No	Development	Amount in \$
1	71.5 High-speed transit system consisting of 33 stations serving 17 communities	6,601,188,875
2	The rebuilding of 3.5 miles of the San Francisco Municipal Railway	
3	Additional Cost of Transbay tube issued by the California Toll Bridge Authority and secured by future Bay Area Bridge revenues	1,108,532,980
4	Cost of rolling stock funded primarily from the bonds issued against future operating revenues	591,773,245
Total Cost		8,301,495,100

Table 2 The calculated equivalent 2019 price estimation for BART for the three counties in 1962

The price of homes near BART stations is very high. The Pittsburgh/Bay Point BART stop, the farthest station from downtown San Francisco, is the least expensive at \$219 per square foot (Graff & SFGATE, 2016). Fig 1 is interpreted by *Estatefy*⁷ shows the average housing cost near BART stations.

⁷*Estatefy* is a United States national real estate company that’s innovating the home buying experience. People can search through millions of listings in 39 states on Estatefy.com. This data is derived from both city’s tax lot data and the amenities available in different locations (“What is Estatefy?”)



Figure 2 Map is showing the average cost of housing per SqFt near BART stations. Source: Estatefy

1.1.1 Not Planned for today's Silicon Valley

Back in 1962, there was no internet, and no one could predict the rise of Silicon Valley in the 1990s.

As Tony Bradley has observed, "Today, Facebook, Twitter, Box, and other technology giants have gone public and amassed billions of dollars of value with the ring of the stock market bell in the Valley" (Bradley, 2019)⁸. Recently, the continued development in this region is predicted to add

⁸ Bradley, T. (2019, January 13). Nat Geo Explores Origin Story of Silicon Valley With "Valley Of The Boom." Retrieved February 17, 2019, from Forbes website: <https://www.forbes.com/sites/tonybradley/2019/01/13/nat-geo-explores-origin-story-of-silicon-valley-with-valley-of-the-boom/>

more than one hundred thousand jobs over the next two years (Lee, 2018)⁹. How the private companies are addressing this issue is investing in the funding of transit projects that help address the growing traffic in California. According to Lee, “In 2018, Facebook had entered into negotiations with the San Mateo County Transit District to improve the Dumbarton corridor, a critical connection point between the company’s bayfront headquarters in Menlo Park and cities on the east edge of the bay such as Fremont and Newark” (Lee, 2018).

1.1.2 The Plan of the BART Extension in 2016

Due to the subsequent requirements of the Bay Area, BART had planned to extend its construction to areas of Silicon Valley, Stockton and Brentwood. BART in Silicon Valley seemed to be the most important one of them all because it had the potential to resolve the everyday traffic that seemed to become inevitable in those locations. (VTA BART, 2018)¹⁰

Developments for the Silicon Valley extension included “a planned 16-mile six station extension of the existing San Francisco BART system.”(VTA BART, 2018)The Santa Clara Valley Transportation Authority (VTA) is the organization that manages BART in Silicon Valley. According to the plan, there are two phases for the project. Berryessa Extension is under phase 1 including two stations and first 10 miles of the project while phase 2 includes the proposal of four stations which are “Alum Rock/ 28th Street, Downtown San Jose, Diridon, and Santa Clara”. The last 6 miles of the extension will include 5-mile-long subway tunnel through Downtown San Jose extending from

⁹ Lee, W. (2018, June 8). Fast-growing Facebook wants to fix Dumbarton rail bridge - SFChronicle.com. Retrieved February 17, 2019, from <https://www.sfchronicle.com/business/article/Fast-growing-Facebook-wants-to-fix-Dumbarton-rail-12974135.php>

¹⁰ VTA BART. (2018). VTA BART Silicon Valley - BART Silicon Valley. Retrieved February 17, 2019, from BART Overview website: <http://www.vta.org/bart/overview/bartsiliconvalley>

phase 1's terminal. According to VTA, the average weekday ridership is expected to be 52,000 in the Silicon Valley region in 2035. (VTA BART, 2018)¹¹ Figure 2 shows the current BART lines in the San Francisco Bay Area.

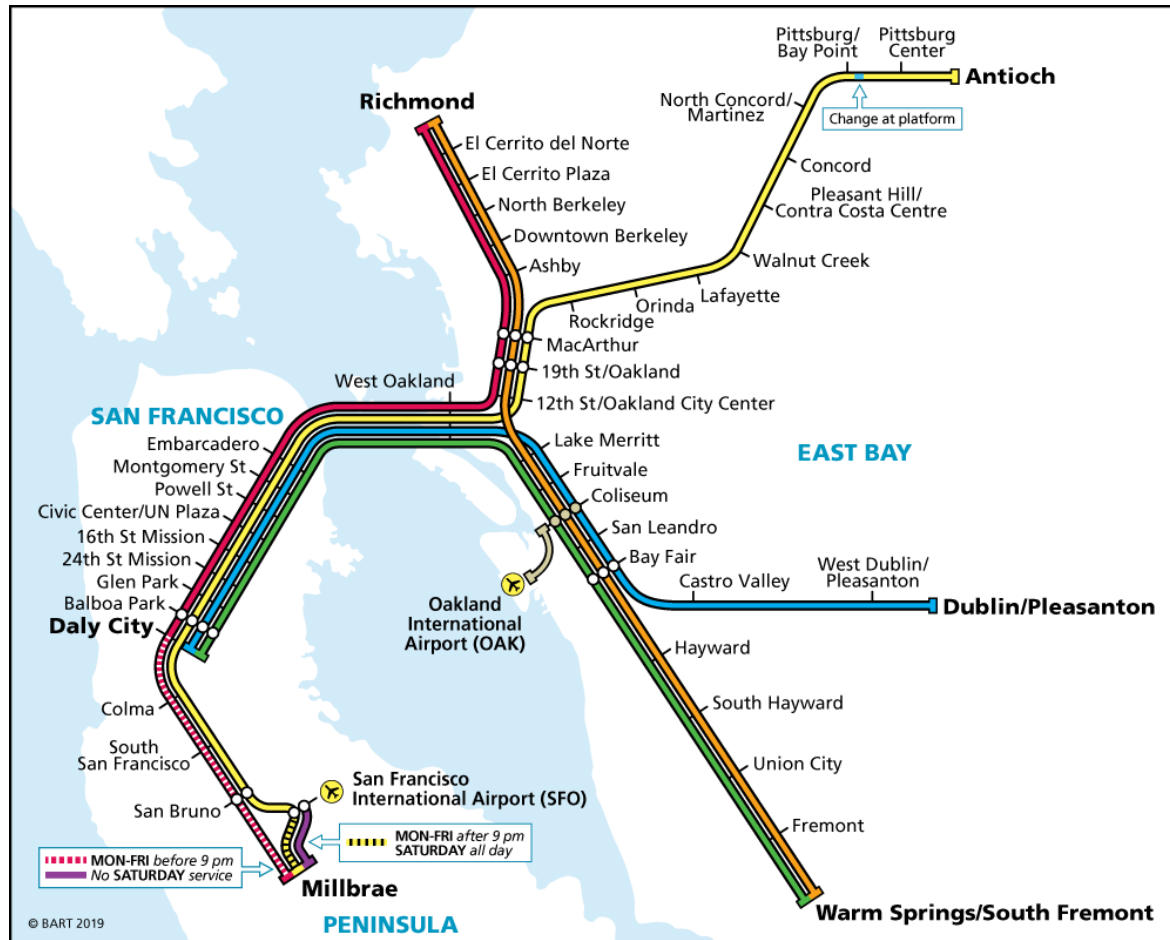


Figure 3 The current BART Map. Source: <https://www.bart.gov/system-map>

Figure 3 shows the proposed extension map of BART in the San Francisco Bay Area.

¹¹ VTA BART. (2018). VTA BART Silicon Valley - BART Silicon Valley. Retrieved February 17, 2019, from BART Overview website: <http://www.vta.org/bart/overview/bartsiliconvalley>

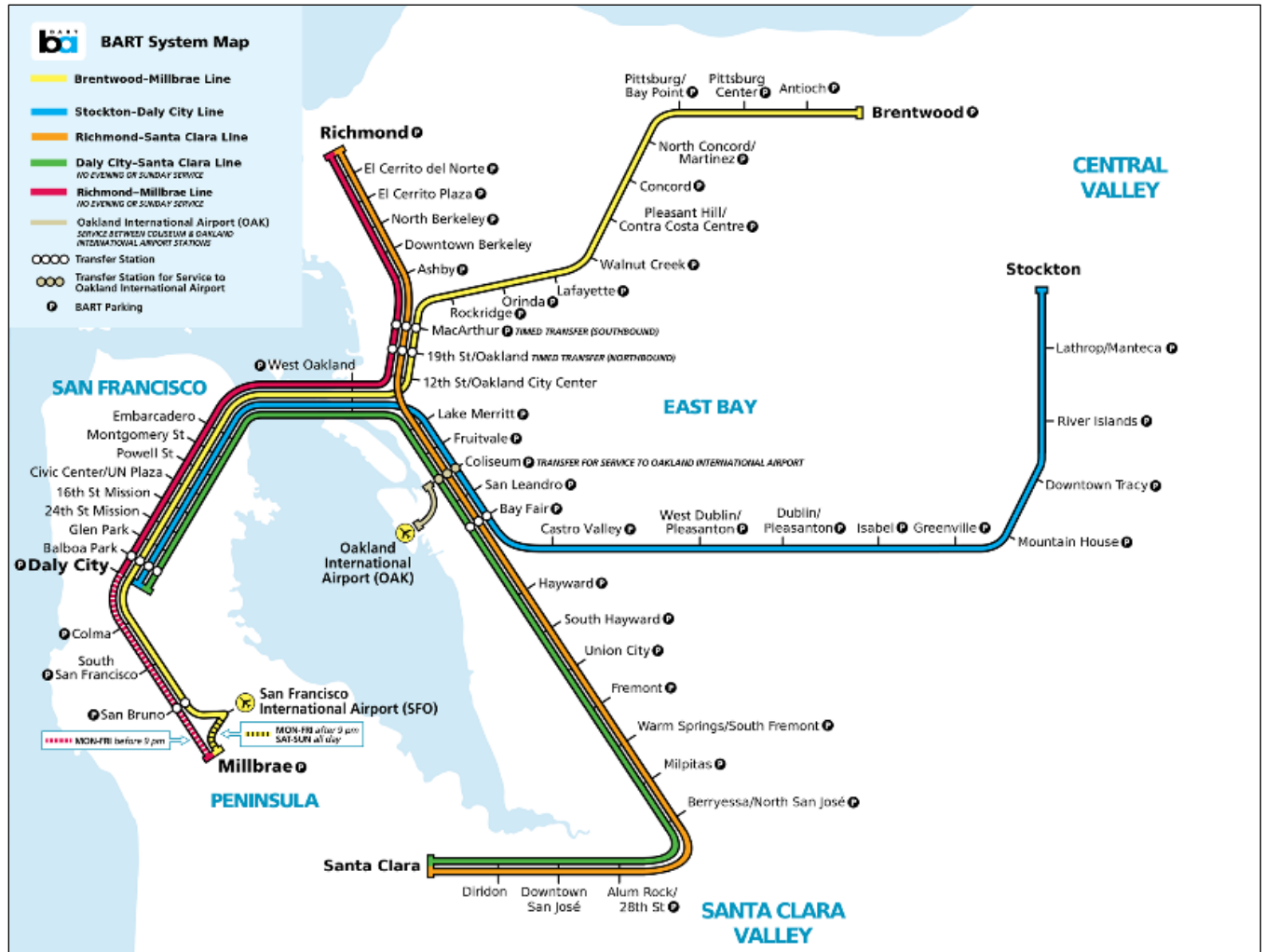


Figure 4 The proposed extension map of BART of San Francisco Bay Area. Source: <https://i.redd.it/a67ne384eje11.png>

1.2 Caltrain

The other major transportation service in the San Francisco Bay Area had been the Caltrain before BART's arrival as a public transportation service.

Caltrain provides commuter rail service in along the San Francisco Peninsula, through the South Bay to the San Jose and Gilroy region. Its first partial service started in 1863. In 1996, an agreement was signed between the Santa Clara County Transit District, the Santa Clara County Valley Transportation Authority, the City and County of San Francisco and San Mateo County Transit District to have a joint right over the Caltrain that we know it today (Caltrain, 2017)¹².

Caltrain serves 28 stations between San Francisco and Gilroy on weekdays(Caltrain, 2018). These stations also include Millbrae station that provides transfer to BART. Caltrain has 134 passenger cars (a coach or a carriage) with 92-weekday trains, 22-weekday express trains, 68-weekend trains, and eight-weekend express trains. (Caltrain, 2018)

1.3 Uber and Carpool apps

Garrett Camp founded Uber in 2009 whose headquarters are currently in San Francisco Bay Area. (Seth, 2018)¹³ It is a transportation network company that offers peer-to-peer ridesharing around the world now. Due to the possibility of ridesharing and getting different types of rides, it has become very popular in the San Francisco Bay Area.

¹² Caltrain. (2018). *Caltrain Fast Facts*. Retrieved from http://www.caltrain.com/Assets/_Public+Affairs/Fact+Sheets/TA+Fact+Sheet+FY2017.pdf

¹³ Seth, S. (2018, March 20). Who is Garrett Camp, Uber Founder and Crypto Inventor? Retrieved March 19, 2019, from Investopedia website: <https://www.investopedia.com/tech/garrett-camp-uber-founder-crypto-inventor/>

Scoop and Waze are carpooling services introduced recently. Scoop started in 2014. The business strategy of Scoop is based on the assumption that rather than focusing on one user Scoop will focus on a large number of employers, office parks and governments agencies (Helft, 2017)¹⁴. Scoop then uses its ride matching methodology to match riders and drivers. Sustainable operation of this system is based on users communicating with their colleagues about it (Helft, 2017). Waze is also a similar app but had started much more recently.

1.4 Other transportation modes

The Muni system includes buses, light rail metro trains, streetcars, and cable cars that cover most of the San Francisco region. It is one of the safe, convenient and environmentally friendly means of transportation there (fpadmin, 2017)¹⁵. Similar to Muni, SMART (Sonoma Marin Area Rail Transit) is also a transportation option providing passenger rail service within the San Francisco region and connects Sonoma and Marin County regions in the North Bay. (SMART, 2016) VTA (Santa Clara Valley transportation authority) serves the South Bay region which provides both rail and bus service. It has connectivity between Alum Rock, Santa Teresa, Mountainview, Winchester, Chynoweth and Almaden regions. (VTA 2018) Amtrak which is a rail system throughout the United States also connects the San Francisco Bay Area and the Northern California region but with a limited number of stations in the region to serve as a main public transportation facility for the residents of the Bay area region. (Amtrak, 2018). The Altamont Corridor Express (ACE) is also a rail system that connects the South Bay region with places beyond the East Bay, Tracy, and Stockton.

¹⁴ Helft, M. (2017, November 8). With \$36 Million In Financing, Scoop Wants To Make Carpooling Mainstream. Retrieved February 20, 2019, from Forbes website: <https://www.forbes.com/sites/miguelhelft/2017/11/08/with-36-million-in-financing-scoop-wants-to-make-carpooling-mainstream/>

¹⁵ fpadmin. (2017, June 13). Muni [Text]. Retrieved March 19, 2019, from SFMTA website: <https://www.sfmta.com/muni>

(acerail, 2018)¹⁶. Therefore, it cannot serve Bay Area exclusively Alameda- Contra(AC) Costs transit, and the SamTrans are the major bus agencies in the Bay area. (AC Transit, 2018)¹⁷ AC transit connects San Francisco, San Mateo, and Santa Clara counties while SamTrans connects San Francisco and Santa Clara County. (SamTrans, 2018)¹⁸

Apart from rail and bus services, there is a regional public bike sharing system servicing the cities of San Francisco, Oakland, Berkeley, Emeryville, and San Jose. The service calls itself, “ a fun and affordable way to get around.” (forgobike, 2019)¹⁹ The service is available throughout the day and the week. Although the region has developed a lot of bike-friendly strategies for its people, San Francisco has seen a decline in bike riders. (Smith, 2019). The speculation for the reasons has been the number of cars parked on the streets and cheaper-safer rideshare services. (Smith, 2019)

1.5 Value to Planners

Cars, traffic, and public transportation play a vital role in determining the efficiency of cities. They link to residents with employment, public services, shopping and social networks, and business to labor, consumer and supply markets. Transportation development strategies are included under the regional development vision of cities because they extend beyond the local jurisdiction. The Comprehensive Economic Development Strategy (CEDS) process for which public public transportation is a major contributor, required by the Economic Development Administration (EDA) to receive funds for capital investment, is an important planning tool used by local officials,

¹⁶ acerail. (2018). Home - ACE | Altamont Corridor Express. Retrieved March 19, 2019, from <https://www.acerail.com/>

¹⁷ AC Transit. (2018). AC Transit | Alameda-Contra Costa Transit District. Retrieved March 19, 2019, from <http://www.actransit.org/>

¹⁸ SamTrans. (2018). samtrans.com. Retrieved March 19, 2019, from <http://www.samtrans.com/>

¹⁹ fordgobike. (2019). The Bay Area's bike share program. Retrieved March 19, 2019, from Ford GoBike website: <http://www.fordgobike.com>

employers, and community leaders to guide future actions (Walzer & Henriksen, 2009)²⁰. Also, public transit benefits communities as it creates more jobs, reduces air pollution, increases fuel efficiency, increases mobility, assures safety and encourages healthier habits among communities. This research could help in providing insight and solutions to the strategies employed in various other cities or regions that are suffering similar problems to those of the San Francisco Bay area.

²⁰ Walzer, N., & Henriksen, M. (2009). *Role of Transportation Planning in the Comprehensive Economic Development Strategy Process: A Nationwide Scan*.

Chapter 2. Research Question

This thesis has two objectives. The first objective is to identify the factors have led to a decrease in ridership in BART and the second is to identify the impacts that other modes of transportation have had on this. This research also aims to critically analyze strategies already taken by BART to understand the projected betterment of the current situation. Objective one answers the following questions:

- 1) What are the main issues that led to the decline of BART ridership after steady growth in the three years before 2018? What are the long term and short-term strategies that BART is adopting to resolve these issues?

The second objective of this thesis is to critically analyze the factors that played a major role in the decline in BART ridership with other commuter modes that are in the San Francisco Bay Area.

Objective two of this research answers the following question:

- 2) What strategies can be adopted by BART along with the other modes of transportation so that all the transit agencies are benefitted?

Chapter 3. Literature Review

This section aims to explain the issues that BART has been experiencing and the impacts that alternative modes had over BART ridership through scholarly research, articles, reports and newspaper articles. Due to high housing rents near the stations, “populations have grown faster away from the stations rather than near the stations” according to John Landis and Robert Cervero (Cervero & Landis, 1997). Hence, people of the Bay Area travel long distances to work.

3.1 BART’s problems leading to the decline in its ridership

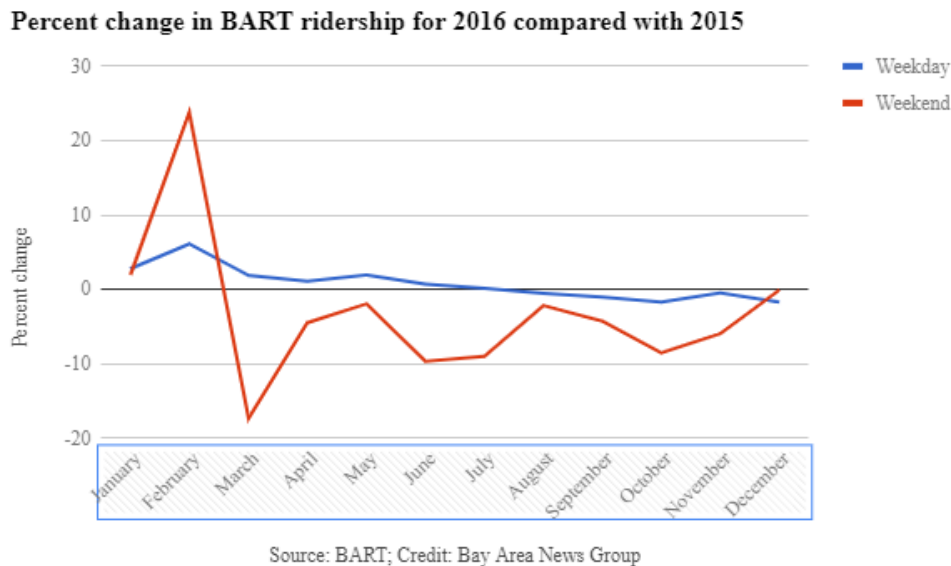


Figure 5 Image shows the percentage change in BART ridership for 2016 compared with 2015

A report by SFGate in 2017 suggested that ridership in BART has been declining during weekends, during non-peak hours and also during the peak hours. The author of the article “With ridership down, complaints up, BART to look at homeless problem” stated that the reasons for this condition

were ridership dissatisfaction, crowded trains and unreliable service (Cabanatuan, 2017a)²¹. A writer at SF News, Jay Barmann, reported in 2017 observed that overcrowding in trains during the peak hours has resulted in lowering the ridership. (Barmann, 2017)²². Due to the decline in ridership, BART had to face an economic debt within the system. Hence, the BART directors cut consultant costs by 10 percent, and they put in place a hiring freeze. Base fares were increased, and the service started at 5:00 AM instead of 4:00 AM. (Barmann, 2017). According to John F Curtin, there is a direct relation between price rise of the tickets and loss of transit riders according to the research he conducted. (Curtin, 1968). The price rise and other changes within BART were supported by Scott Morris of *Oakland Magazine* who said that the serious financial problems within BART were due to the expansion of BART without proper prior estimations of ridership later. (Morris, 2017)²³

Cabanatuan mentioned the reasons for the decline in ridership were because passengers felt uncomfortable with dirty stations, open drug use and debris, and homeless people sleeping and lingering in stations and panhandling (Cabanatuan, 2017a). Laura Bliss, a staff writer at CityLab about transportation and technology suggested a different outlook for the ridership decline. She said in one of her reports that people are buying more cars and tending to do those activities on the weekends that are better served by their own car. Hence, people have started feeling that traveling by transit is a less attractive option. (Bliss, 2017) Another issue faced by officials was that BART stations did not have adequate parking lots near them making it impossible for some of the riders

²¹ Cabanatuan, M. (2017a, May 12). With ridership down, complaints up, BART to look at homeless problem. Retrieved February 20, 2019, from SFGate website: <https://www.sfgate.com/bayarea/article/With-ridership-down-complaints-up-BART-to-look-11140277.php>

²² Barmann, J. (2017, February 24). Overcrowded BART Trains Likely Causing Drop In Ridership, Ironically: SFist. Retrieved March 24, 2019, from SFist - San Francisco News, Restaurants, Events, & Sports website: https://sfist.com/2017/02/24/overcrowded_bart_trains_likely_caus/

²³ Morris, S. (2017, May 30). Has BART Overexpanded? Retrieved March 24, 2019, from <http://www.oaklandmagazine.com/June-2017/Has-BART-Overexpanded/>

who wish to travel by both BART as well as their car (Brock, 2019). He also added that many stations have severely damaged equipment that leads to train delays. According to a journal report, unreliability implies a shift of attention from the supplier towards the customer (Rietveld, Bruinsma, & van Vuuren, 2001). Hence, commuters may stop trusting BART.

According to scholarly research conducted by Osman, Thomas, Mondschein and Taylor, it was found that new firms or companies are often more likely to start up in already congested areas. This research suggests that Silicon Valley would get more and more congested as the years pass by. (Osman, Thomas, Mondschein, & Taylor, 2019)²⁴. So, is the expansion of BART to San Jose and Santa Clara a good decision by BART?

3.1.1 BART's Strategies

The first step taken by BART to deal with the homeless people in the stations was to join with the San Francisco Transportation Municipal Agency, San Francisco's homeless outreach teams, and social service agencies. These agencies planned to provide alternative shelter for homeless people to reduce their number in the stations. (Cabanatuan, 2017a) For the parking problem, one of the strategies that were decided to be incorporated into the BART parking system policy was to create a permit for carpool drivers which would let commuters share a spot which can be booked using the BART mobile app. (Brock, 2019)²⁵ According to Rodier and Shaheen, a newly developed smart parking system at the Oakland BART station had resulted in changes in commuter behaviour-

²⁴ Osman, T., Thomas, T., Mondschein, A., & Taylor, B. D. (2019). Does traffic congestion influence the location of new business establishments? An analysis of the San Francisco Bay Area. *Urban Studies*, 56(5), 1026–1041. <https://doi.org/10.1177/0042098018784179>

²⁵ Brock, S. (2019). BART Tries to Find a Solution to Parking Issues. Retrieved February 21, 2019, from NBC Bay Area website: <http://www.nbcbayarea.com/news/local/Daly-City-BART-Station-Tries-to-Find-a-Solution-to-Parking-504897881.html>

increase in BART mode share, decrease in drive alone mode share and overall reduction in total vehicle miles of travel(Rodier & Shaheen, 2010). BART also has incentives for children and old people and everyone during the weekends. (BART, 2018) Apart from these, BART's extension to Silicon Valley and other regions where there was no BART before is the major project taken by BART to improve BART's connectivity and ridership to serve more people of the Bay Area (BART, 2019c)

3.2. Caltrain impact

As mentioned earlier in this study, Caltrain is a commuter rail connecting San Francisco to San Mateo and Santa Clara counties where BART is connecting San Francisco with Alameda and Costa County regions(Caltrain, 2017).

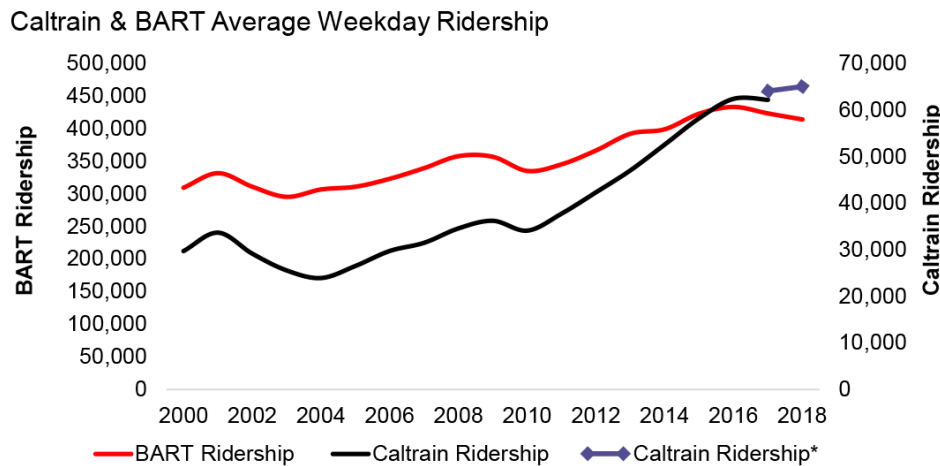


Figure 6 Ridership analysis of BART and Caltrain by JLL

According to a research conducted by (Jones Lang LaSalle) JLL research team, while BART experienced a decline in average weekday ridership between the two years 2016 and 2018 following

six years of steady growth, but Caltrain's ridership grew during this period as shown in Figure 2 in the same region where both the parties serviced. (JLL Research, 2018)²⁶

According to a report by Andy Boselman, Caltrain was providing service to San Francisco from Millbrae Station for a long time while BART added its service as part of its \$1.6 billion expansion to the San Francisco international airport. The current Millbrae region is overbuilt for the average number of riders enter and exit the station. According to Alon Levy, a mathematician who eventually turned into a transportation expert, both Caltrain and BART are competing with each other rather than serving its commuters (Boselman, 2018). He also felt that both Caltrain and BART do not have reliable connectivity to bus agencies like Muni, AC Transit or SamTrans.

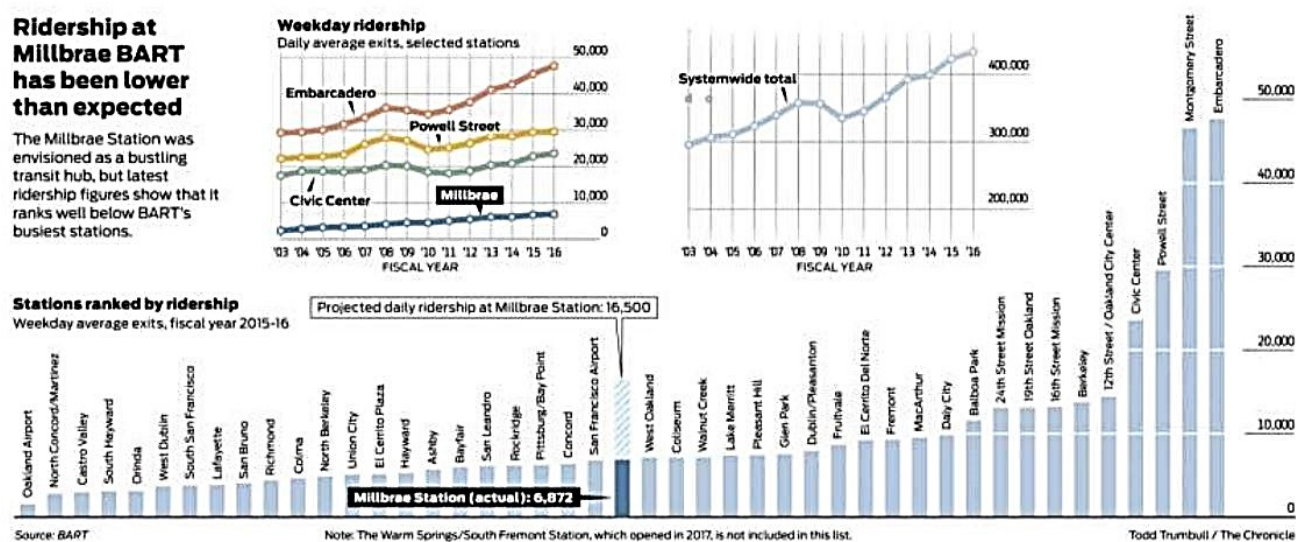


Table 3 Graph showing ridership at Millbrae BART has lower than expected. Source: <https://www.sfchronicle.com/bayarea/article/Millbrae-BART-Station-ridership-isn-t-near-11265998.php>

Before BART had extended into the region where Caltrain was already existing, it served about 7,000 passengers daily. The ridership did not grow to what was expected after its construction

²⁶ JLL Research. (2018, December 4). BART ridership continues to decline while Caltrain sees slight uptick year over year. Retrieved March 24, 2019, from <https://www.us.jll.com/en/views/snapshots/san-francisco-bart-ridership-declines>

(Bosselman, 2018)²⁷. This was also observed by others during the same time, Cabanatuan, a writer at San Francisco Chronicle about transportation-related topics for a decade reported the same in his article, “ Millbrae BART Station ridership isn’t near original expectations.”(Cabanatuan, 2017b). A single track would have been more functional than four as trains that ran through this station had a fifteen minutes gap in between them according to Levy.

Levy also explained that BART wanted to have its own separate route though it could have shared with other railroads (Bosselman, 2018) Supporting this assertion, Irvin Dawid, an environmentalist and a frequent writer at *Planetizen* from the Bay Area, suggested that politics played a vital role in both BART extension to the SF Airport and the overbuilding of the Millbrae station. He said that the senator during that time, wanted to see BART go directly to SF International Airport rather than a shared Caltrain BART SFO AirTrain station. (Dawid, 2017)²⁸ This, in turn, resulted in the sharing of riders between the two services. Hence, the competition and political situations lead to fall in ridership between BART and Caltrain.

3.3. Uber impact

Uber was founded in 2009 with its headquarters being in San Francisco Bay Area. Both Travis Kalanick and Garrett Camp played a pivotal role in making this ride-hailing system possible and successful around the world. Though other ride-hailing systems are competing against this system, it remains as the best one among all the others(Iqbal, 2018). Uber has a significant impact on BART’s

²⁷ Bosselman, A. (2018, June 18). Bay Area subway and rail costs: Why are they among the highest in the world? Retrieved February 22, 2019, from Curbed SF website: <https://sf.curbed.com/2018/6/18/17464616/bay-area-subway-train-rail-costs-price-bart-muni>

²⁸ Dawid, I. (2017, July 16). Why was BART’s Ridership Forecast for Millbrae Station So Wildly Off-Base? Retrieved March 24, 2019, from Planetizen - Urban Planning News, Jobs, and Education website: <https://www.planetizen.com/node/93755/why-was-barts-ridership-forecast-millbrae-station-so-wildly-base>

ridership. According to Barb Darrow, a Fortune²⁹ website writer, these ride hailing systems have decreased the use of more efficient public transit(Darrow, 2017).

Aarian Marshall wrote in *Wired*³⁰ about a study, “TNC’s and Congestion in October 2017 on vehicle delays in San Francisco and said that “The report concludes that Uber and Lyft were responsible for 51 percent of the daily vehicle delay hours increase between 2010 and 2016. During the same period, these companies accounted for 47 percent of the increase of vehicle miles traveled, and 55 percent of the average speed decline on roadways. Population and employment growth, plus changes in the road network, accounted for the other delays.” (Marshall, 2018)³¹ The increase in miles would also mean that some of the BART riders had started using ride hailing systems due to their convenience.

According to an article written by Bruce Schaller, the deputy commissioner for traffic and planning in New York City, the greatest number of riders for ridesharing trips of both Uber and Lyft happen in densely populated metropolitan areas. From his report – “The New Automobility: Lyft, Uber and the Future of American Cities” which studied different metropolitan cities in the United States, he found out that 75 million trips occurred in San Francisco through apps such as Uber in 2017(Schaller, 2018). One of his most interesting observation was that “shared rides add to traffic because most users switch from non-auto modes,” according to Schaller. Faiz Siddiqui said “Also, there is added mileage between trips as drivers wait for the next dispatch and then drive to a pickup

²⁹ Online news letter service that publishes reports on politics, finance, entertainment and international news

³⁰ Wired is a monthly American magazine, published in print and online editions, that focuses on how emerging technologies affect culture, the economy, and politics.

³¹ Marshall, A. (2018, October 16). Uber and Lyft Made Traffic Worse in San Francisco. But It’s Complicated. *Wired*. Retrieved from <https://www.wired.com/story/uber-lyft-san-francisco-traffic-report/>

location. Finally, even in a shared ride, some of the trips involve just one passenger.” (Siddiqui, 2018) This confirms that Uber can never be like a public transit system.

A team of students from the University of California, Davis recorded patterns of people who used ride-hailing services in October 2017. According to this research, once an individual started using a ride-hailing service, that individual is less likely to use public transit. The report asserts: “ride-hailing attracts Americans away from bus services (a 6% reduction) and light rail services (a 3% reduction).”(Regina & Mishra, 2017) This study suggests that even if BART had started many incentive programs, people would still use ride hail services as they have got used to it now.

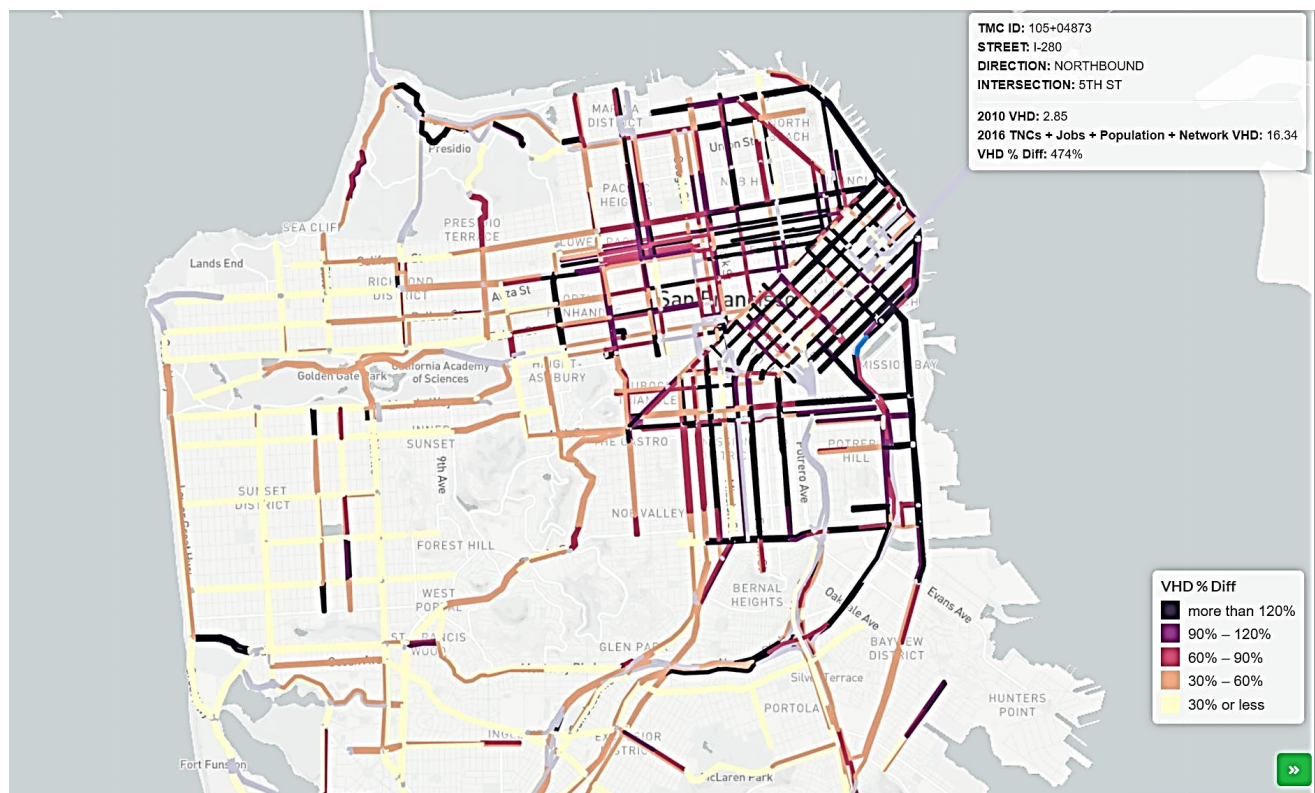


Figure 7 A map of San Francisco showing the change in vehicle delay hours. The sections in yellow show roads where delays were decreased by 30 percent or less; the areas in dark purple show the roads where delays increased by 120 percent or more. Source: San Francisco County Transportation Authority

Along with Schaller's theory, Uber was supporting several policies mentioned by him such as the expansion of dedicated bus and bike lanes and congestion pricing. They also boasted about the fact that with their development they were able to save more than 315 million global vehicle miles in 2017 by shifting riders to rideshare pool service. (Siddiqui, 2018). The other positive result found by UC Davis students for ride-hailing was that these services could complement the use of commuter rail. Their survey showed a 3 % increase of commuter rail usage among the individuals who started preferring Uber or Lyft over public transit. According to a report on *NerdWallet*³² by John Kuo, in some states in the US, the expense of owning a car is much more than traveling by Uber and Lyft (John, 2014). The differences in expenditures would add to ride hailing ridership drastically at least in those cities where it may be cheaper than owning a car, adding a greater decline to public transit. This also had other benefits. According to a paper about the impact of ride-hailing services over public transportation, these services provided a “solution to “last-mile” problem and by providing a potentially safer option at night when public transportation service has been reduced”(Sadowsky & Nelson, 2017).

3.4. Carpool impact

Similar to mobile-based transportation services like Uber and Lyft, Scoop uses machine learning technology to aggregate demand and to match drivers and riders. Unlike other ride-hail services, Scoop caters to employees. Currently, it is primarily used in the Bay Area and Seattle (Helft, 2017).

³² NerdWallet is an American personal finance company, founded in 2009. It offers a website and app that aims to assist users in making personal financial decisions.

3.4.1. How Does Scoop Work?

According to the Chief Product Officer of Scoop, it was created to make coordination simple. Just like the ride-hailing services, the Scoop app looks for the fastest routes and estimated time of arrival. In this service, one can also rate co-riders along with drivers. Incentives are provided to both riders and drivers when cancellations happen. These are some of the benefits of using carpooling services.

Scoop's major competitor has been Waze carpool. This app makes the riders to go to a centralized location rather than making the driver go to the rider's home/office location for picking up. Hence, this makes it more driver-friendly as compared to Scoop. The concept of carpooling not only helps people reach their destination faster but also provides a better social life while traveling by cars.

San Mateo's County's Transportation Demand Management Agency, a public agency, has started 'Carpool 2.0 Rewards Program'. This program is aimed at increasing local carpool ridership during peak travel periods to reduce single-occupancy vehicles, traffic and need for parking within the San Mateo region. The drivers are rewarded with e-gift cards ranging from \$25 to \$100.(Commute.org, 2019) During the same time, Foster City commuters also witnessed similar incentives from the city agencies according to a report by *TechCrunch*(Kolodny, 2017). Another incentive system provided to the UCSF (University of California, San Francisco) is that they could take advantage of special discounted rates if they register the app using their UCSF email, and enter UCSF Mission Bay as their start or end destination during the pilot period. (Scoop Carpool, 2018).

Even before the public agencies started incentivizing carpooling, private companies had started doing the same in 2016. For example, according to another report by *TechCrunch* written by Megan Rose Dickey said that "At Cisco, the company subsidizes the rides so that employees only have to

pay 1\$. Workday, Stanford Research Park and Tesla are also subsidizing rides for their employees.”(Megan Rose Dickey, 2016.). While the public agencies had an intention to reduce traffic congestion and reduce emissions of hazardous gases into the air, private companies also had their own goals. They wanted their employees to have an easy commute to their offices which would, in turn, make them more efficient at work.

Michelle Quinne, a former business columnist for the Bay Area News Group, agrees in an article at *mercury news* “I don’t think carpool apps can save humanity or even the planet.” (Quinn, 2017) But she would keep using them because she can exercise her right to use the HOV(High Occupancy Vehicle) lane and because carpool apps made things a little bit better for everyone. (Quinn, 2017)³³

Chapter 4. Methodology

Methodology for this study is divided into two parts and focuses in the region of the San Francisco Bay Area. The first portion is a qualitative analysis which includes a survey of BART commuters and interviews with BART officials as well as Scoop riders and drivers. The second part includes a quantitative analysis of ridership details between BART and Caltrain. In addition to that, it also includes an analysis of Uber ride costs through Uber API. The collected results are then analyzed and compared with the literature search for a better understanding of the decline in ridership in BART.

³³ Quinn, M. (2017, January 3). Road warriors unite: Carpooling apps won’t save the planet but may help us save each other. Retrieved March 24, 2019, from The Mercury News website: <https://www.mercurynews.com/2017/01/03/road-warriors-unite-carpooling-apps-wont-save-the-planet-but-may-help-us-save-each-other/>

4.1. Survey with BART Commuters

Seventy-Eight commuters from random stations were asked to fill in a survey that was created in *surveymonkey.com* either through their mobile device or on a laptop device. All of the interviewees responded although four individuals skipped some questions. At the beginning of the interview, information regarding the study was explained to the interviewee, and verbal consent was approved for proceeding further. The questionnaire (Appendix 1) contained eight questions. The general questions that were asked to the commuters were their age range, the field of work in which he or she was involved in, and where their workplace and home were situated in the Bay Area. Some of the subjects were not willing to tell the names of their office/home location. Hence, they were allowed to skip questions they did not want to answer. The skipping of questions could have caused some errors in the findings of this study such as a not appropriate indication of prediction on the histograms that were created based on the survey. Specific questions in the same questionnaire asked the subject to tell if he/she owned a car or not and why would he/she prefer to travel by BART even if he/she owns a car. They were then asked to choose which mode of transportation they think is the best mode to reach their office and when do they tend to use BART if they did. Finally, they were asked what they think is the biggest drawback of BART.

4.2. Interviews with BART officials

Initially, this was initially intended to be done by phone calls or personal interviews at BART stations. But BART officials are not allowed to participate in surveys/interviews during their work hours, and due to their busy schedules, most of them were not willing to remain after their office hours or come early before their shift to participate. Hence, a questionnaire was made for BART on *surveymonkey.com*. The questionnaire was then distributed to the members of the staff who were the district directors of BART for different counties through e-mail after explaining the purpose and

getting approval for their consent. Some forms were also distributed to BART officials that were found on LinkedIn.

The questionnaire (Appendix 2) had open ended questions allowing the subjects to write whatever they wanted to fill in rather than choosing from a given set of options. This survey was to understand if the BART officials were aware of the problems faced by the commuter and to understand what long-term and short-term measures BART had taken and had decided to take in the upcoming future to minimize the decline in ridership that was witnessed in the Bay Area. The questionnaire had six questions. The first question asked about the subject's job title and the second one was about how many years that the official was serving BART to determine if the individual was under BART during the various ridership shifts that BART faced over the years. The third question asked their opinion on BART ridership currently and in prior years. The fourth one asked the officials to name a few strategies that had been taken to increase ridership. The fifth question specifically asked the names of stations that would be added to the BART system in the future. The sixth question asked the BART officials their views of how much are the commuters aware of the facilities, security helplines, and BART mechanisms. It also asks them to note down the frequent questions or problems that the commuters bring to them every day.

According to the *SurveyMonkey*, the subjects took at least 10-20 minutes to fill the questionnaire, unlike the survey that was conducted with the commuters. Nine officials took the survey. The officials included two senior planners, technical publications administrator, principal architect, a director of district 4, group manager of station area planning, strategy and policy planning manager, principal planner and program manager of reliability and performance.

4.3. Interview with Bay Area Carpool driver and riders

The final qualitative method in this research is interviewing ten of each carpool drivers and riders for understanding their views on carpooling over BART as a transportation mode to travel to work.

Five questions (Appendix 3) were asked for the drivers. The first one asked the origin and destination of their ride. The origins and destinations were to estimate the number of miles that Carpooling generally happens for in the Bay Area. The second question asked the subject to select from available options the reason for driving for others. The options given were the ability to use the carpool lane, the amount of money earned an opportunity to network and socialize with people or other reasons. The third question asked the driver if they would prefer a centralized location instead of picking the riders up from their homes. The fourth question asked the driver why they wouldn't switch to using BART or public transportation considering the traffic in rush hours. The fifth question asked the reason for why they preferred or did not prefer a centralized location pickup of the riders. Ten interviews were conducted for this survey. These interviews were conducted only to understand further the literature search that is already conducted in this study and not for quantitatively establishing major findings.

In another set of interviews of riders, the respondents were asked four different questions (Appendix 4) to understand why they preferred to carpool over BART or other public transit systems. The first questions asked the rider if they think carpooling is better than BART or Uber and why they think that way. The second questions asked the rider if there is BART connectivity to their workplace from their home. And if yes, why would they prefer carpool over BART. The third question asked the rider what would be the next best alternative mode that he or she would prefer if they did not find a carpool match. The fourth and final question to the rider was if they would be willing to walk a little and then get picked up from a centralized location instead of from home if

Carpool apps offer them such an option at a lower price. Usage of apps is also a tech-savvy approach to getting to an office as it has to do a lot with technology, something that people of the Bay Area are willing to have. Ten interviews were conducted of the riders. These interviews were conducted only to understand what made some people of the Bay Area use these services.

Quantitative Analysis

This is the second portion of the methodology of the study. Described in this section are the quantitative approaches used to understand the shifts in ridership and pricing models better in BART and other alternative modes of transportation including Caltrain, Uber rideshare service, carpool services with BART's systems. Hence, this is a combination of quantitative approaches. Certain routes are identified where an alternative mode and BART are servicing, and they are compared critically to understand which system functions better and identifying the factors for the same. There are certain limitations to this method, and they shall be mentioned as the sub-methods are described here in this section.

4.3. Comparing BART and Caltrain

As BART and Caltrain travel in the same location only in the San Francisco region, they are compared with each other only in this region. Different parameters are compared in both transit systems to understand the disparity between them as well.

The first goal here is to find out the difference in ridership details in the years 2017 and 2018. After a brief understanding about the ridership numbers in between different months, calculations are made for the years 2017 and 2018. Caltrain provides yearly data while BART gives only average monthly ridership details. Hence, monthly data of BART ridership is aggregated to yearly data for

further analysis. For this, Python (Appendix 5) is used to do basic testing to compare the number of entries and exits in Millbrae, Embarcadero and Montgomery stations. The second analysis is the pricing models of the two transit systems. Direct comparison between how much it would cost between Embarcadero and Millbrae in BART and the parallel route of the Caltrain on this route is made from the calculators available on the official websites. The time taken in between these two stations is also calculated to understand quantitative factors that affected the commuter's choice of one mode of transportation over the other. The ridership data is collected from the official websites of BART and Caltrain which are open sourced.

4.4. Comparing BART and Uber

The next part of this quantitative analysis includes comparing BART with Uber. For this method, GIS analysis is done to identify five stations on the BART routes that are nearer to relatively populated census blocks as compared to the others because of Uber services the entire Bay Area.

Mapping the stations near high-density population

Blocks of San Francisco Bay Area with different population densities are classified. The layers BART stations and BART routes are overlaid on this. The buffer tool in GIS is used to make half mile radius buffers around the stations as a new layer. Then those buffer regions are identified that contain a population of more than 75000 in each block (I assume that these are more crowded and more active). Five stations that fall in different lines of BART have been selected for further analysis. From them, five routes are considered that are connecting these stations such that these five routes cover most of the lines. Given below are the data sources of the data that was analyzed on GIS.

Variable	Operational Definition	Sources and year
Population density	Population per square mile	Demographic research unit of California (2017)

Census Blocks	Geospatial polygons	US Census Bureau (2016)
BART Stations	Geospatial polylines	
BART Lines	Geospatial points	

Table 4 Data Sources

The next part is to compare BART and Uber. For this purpose, the identified routes from the above process are between the two modes of transport based on pricing and time taken for the route during the peak hours. Peak hours are considered to avoid error and considering the time when the transit is most used. Available Uber API for developers is used for python analysis (Appendix 6) for estimating price for available services provided Uber and time taken for the routes that were already selected in Uber. The time and price for BART were manually derived from the BART website which tells the price and time taken when starting station and end station are input.

4.5. Comparing BART and Carpooling services

For comparing BART and carpooling services in the Bay Area, only those regions are considered where the BART is not servicing well and, in those locations, where carpooling is in abundance in the region. Hence, the San Jose, Mountain View regions and the connection between Oakland and San Francisco and studied as carpooling through apps is more prevalent in the mentioned regions. 511 SF Bay services are the third prominent carpooling service which covers mostly between Oakland and San Francisco region. The selected routes are then compared based on price and time taken during peak hours. As the time taken by the carpool services is not always given in the different carpooling apps, it is manually calculated according to a google map app. Then the time is taken, and the price of different routes are compared between BART and Carpool services for determining the findings.

Chapter 5. Findings

5.1 Surveys and Interviews

The findings from the survey conducted in December 2018 where BART commuters, BART officials and Carpool riders and drivers were interviewed as following. The individual results of the commuters are in the appendix (Appendix 7) in tabulated manner.

5.1.1 Commuter Survey

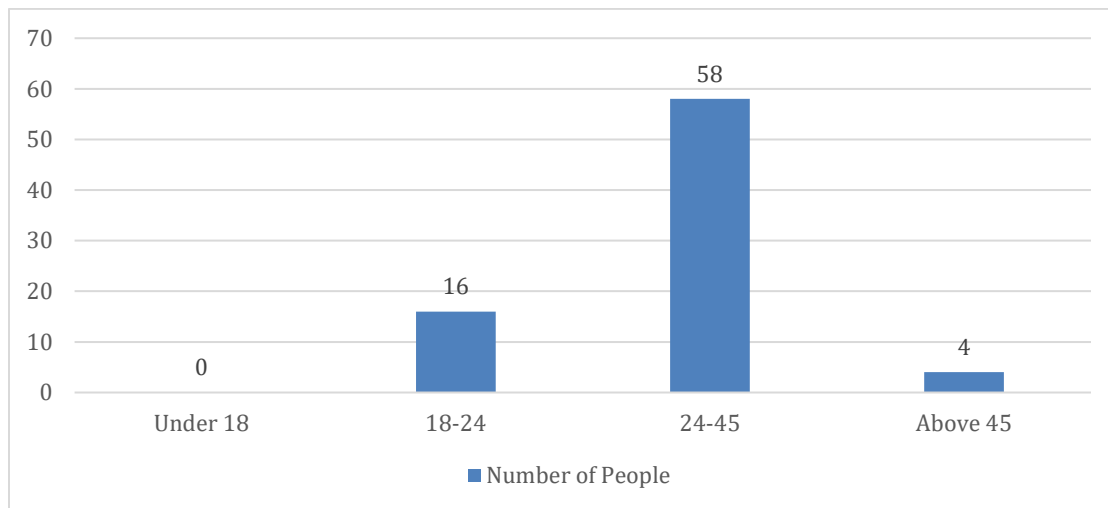


Table 5 Commuter Survey results of age

This survey was conducted with 78 random BART commuters. According to the results of answers received from the commuters for the first question which is indicated in the above graph, 58 people that travel by BART is in the age group 25-45 followed by 16 people of age group 18-24. The answers to this question suggest that BART has to be designed to cater to the needs of young adults and a middle age generation who are either studying or working as officials in the Bay Area.

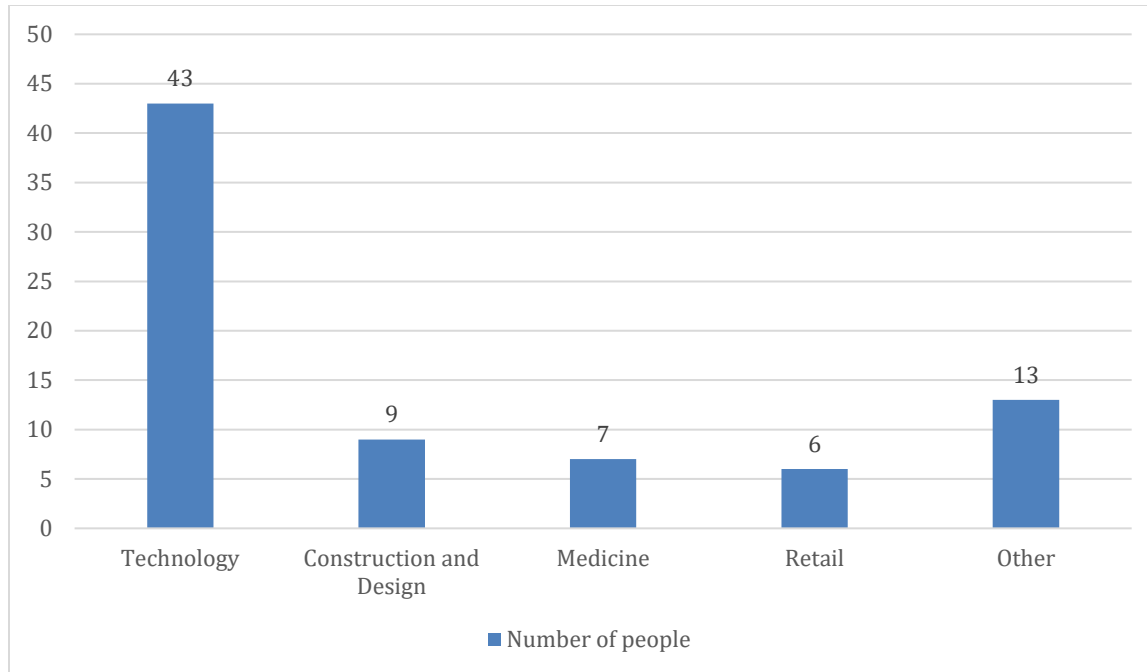


Table 6 Commuter survey results on which field they work

The second question's results suggested that most of the commuters of BART were working in technology. The answers to the second question suggest that BART again has to cater to the crowd that is in the technology field.

The third and fourth questions which wanted the commuters to tell their start point and destination point, prove that people who use BART for going to their workplace traveled by it only when the distances between the workplace and home are at least 10-15 miles. It is also observed that most of the people have their houses in the East Bay while their work is in the West Bay.

From the answers of the fifth question, we can see that people who did not have cars were traveling by BART. In addition to that people with cars and had resided nearer to BART stations preferred traveling by BART rather than driving to avoid traffic. Some of them travel by BART rather than by

their own car to avoid finding a parking lot when they are going to crowded regions and for convenience.

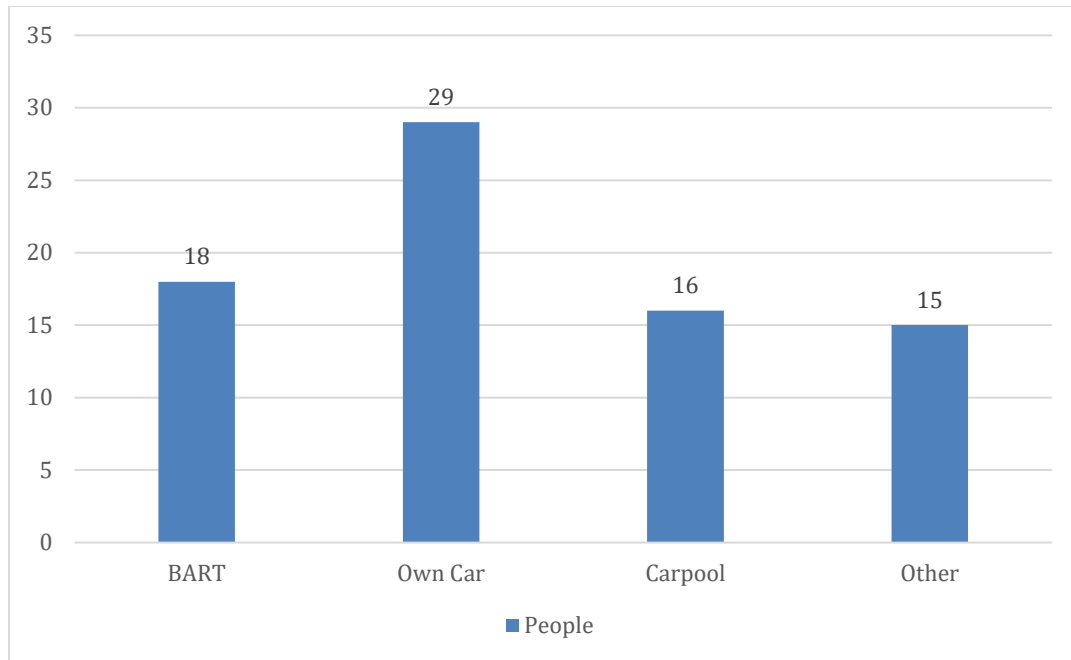


Table 7 Commuter results on which mode they prefer the most

The results of this question strongly indicate that the highest number of the surveyed commuters considered BART as the second best mode of transportation next to riding by their own car. The most important limitation of this indicator is that these questions were asked to those individuals who were using BART. Hence, it is obvious to see BART ranked two in this survey. The carpooling services have ranked third in the survey whereas their own car was ranked first.

For the seventh question, the commuters gave multiple answers, and they all seemed valid as per the situation that they are facing. Many people did not use BART on a day-to-day basis. Many said that they tended to use BART only when they were traveling to the San Francisco region so that they avoided traffic, driving long distances and finding a car spot in San Francisco. Some of them only traveled by BART if they did not get a carpool match indicating that BART is only a secondary option that they preferred over carpool. Some of them also traveled by BART if they were sick or

tired because they wanted to avoid driving which does require some physical strength and concentration while traveling on some of the busiest roads in San Francisco.

The last question asked the commuter to name what they think is the biggest drawback of BART. The replies also were dependent on their situations and where they were living. But most of them indicated that the pricing of tickets by BART is very costly. As mentioned in the literature search, the prices grew due to the financial crisis faced by BART due to overexpansion. They also expressed that there is a serious lack of security. Their concern may be due to recent crimes that have occurred in BART stations. One of the commuters expressed that she thinks it is insane to exit out of BART and then to enter again to Caltrain when she has to transfer at Millbrae station which is because the frequency is low. These factors were also identified through the literature search.

Apart from what was identified in the literature search, some commuters said that BART does its repairs during the weekend which results in some lines getting shut which created a lot of problems and worries for the people who wanted to travel to San Francisco on the weekend. As observed from the survey; many people used BART to reach San Francisco without having to face the intermediate traffic while going to it.

5.1.2 BART official's responses

Interviewing BART officials proved that BART was aware of the current ridership declines although they were not focusing on developing specific strategies to overcome the situation. When the director of district four was asked about what is the change in the number of people who used to take BART and now, he said,

“Daily weekday ridership grew 2010-2016 in conjunction with job growth and rebirth of urban centers. BART's 2015 Station Profile Survey showed that much of this growth was due to active transportation modes. Since 2016 weekday ridership has declined as BART reached capacity in the Transbay commute peaks, the impacts of crime and homelessness have deterred some trips, while TNCs have poached local trips.”

The comment support's Cabanatuan's article in the literature search. When the director was asked about what were the long-term and short-term measures that BART was taking to make BART experience for the people, the director said,

“New train car purchases are now augmenting the fleet, allowing BART to operate longer trains to reduce crowding. Further additions to the fleet and a new Communication Based Train Control will enable BART to continue to grow capacity by operating more frequent service. Interrelated issues of crime, impacts of homelessness, and fare evasion are being addressed by restricting access to only paid passengers through enforcement of a Proof of Payment system and increased station hardening. At the same time, BART is rebuilding aging infrastructure with Measure RR funds (2016) to improve reliability and modernize stations.”

When asked about the recent additions that BART was making in terms of stations, most of the officials talked about the expansion of BART to San Jose with the partnership of Santa Clara Transportation Authority. It seems that two stations were about to be opened in 2019 while the construction of four others was planned. Some other officials talked about the stations that were going to be included in the Warm Springs line which may be because this questionnaire was asked to BART officials all around the entire Bay Area. When asked if BART was aware of its commuters' problems in BART, a senior planner who has been in BART since November 2015 said,

“I believe safety/security issues and cleanliness issues are the most frequent complaints. Latest customer satisfaction survey shows worrying results which have been reported in news and blogs. I'm not sure if customers are aware of all the various BART helplines; however, even if they are aware, BART helplines are not always helpful in addressing problems. BART struggles with always being reactive to problems instead of proactive in avoiding problems.”

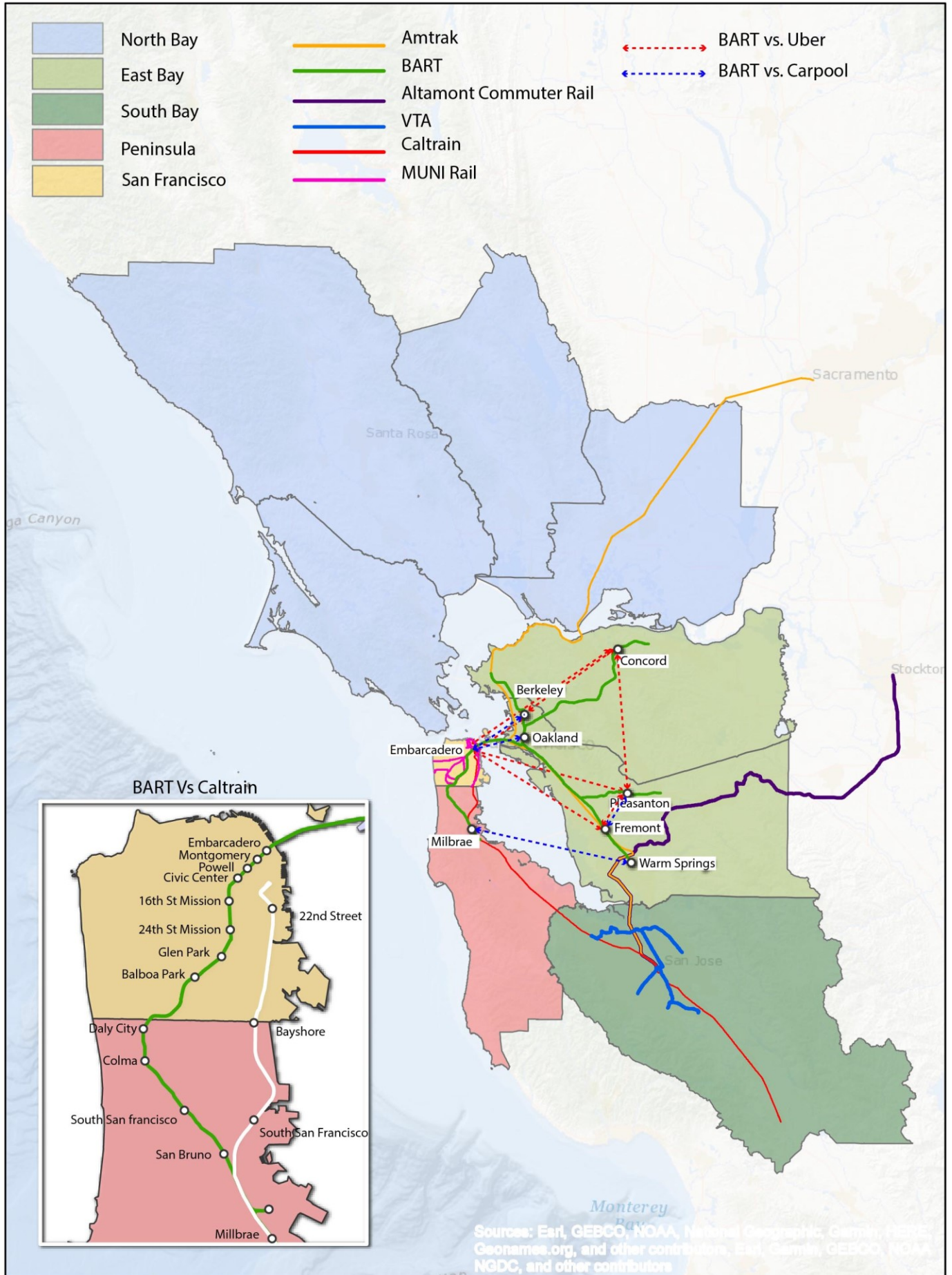
It is clear from the above statements that BART has not been able to resolve all the issues that were faced by the commuters as some of the officials do not even know them.

5.1.3 Carpool rider and driver responses

Although the this survey is not significant due to the respondents being less in number, this gave insight to why some people of the Bay Area preferred carpooling over other transit options. The survey from the carpool riders and drivers corresponded to the theories from the literature review. Most of the drivers were willing to drive for others because they were earning some extra money which they could at least use for buying day to day groceries. One of the interviewees was traveling on the interstate road that was going to his office through Interstate highway 880 which had a carpool lane just like Michelle Quinne in the literature search liked to avail the possibility of using HOV (High Occupancy vehicle lane). He was only eligible to use it only if he had another rider. Hence, although he did not like more riders with him because he did not like collecting from the centralized location, he wanted just one other rider along with him so that he can use the carpool lane and get to his office early. The riders were very happy with the carpooling system. They preferred traveling by carpooling because it was cheaper than Uber and collected them from their home locations more often. When asked if BART is connected to their location, they said no. Hence, it is obvious that people who traveled by carpool were not close to BART or that their workplace was near to a BART station or maybe even both.

5.2 Quantitative Comparison

Quantitative approaches are between BART, and other alternative modes are done to critically understand the benefits and losses between each mode of transportation. Figure 8 shows the different stations and locations that are considered in this study. BART is being compared with Caltrain, Uber, and Carpool services. As different transportation modes only service limited areas, the study considers only those locations where both transport modes are servicing for a better



South San Francisco is considered as this region is serviced by both BART and Caltrain. As Uber is serviced all around the Bay Area, but only those locations are considered which are serviced by BART. Finally, for carpool, mostly the regions in East Bay, Peninsula San Francisco regions are considered as there is service of both BART and Carpool here.

5.2.1 Caltrain and BART Comparison

Caltrain and BART data is available from Caltrain and BART websites are used for comparison. As mentioned earlier, a direct computer-based comparison is done first, and only those stations are considered which are in between Millbrae and San Francisco downtown area, as this is the area where both Caltrain and BART run.

	2014	2015	2016	2017	2018
Jan	381090	410847	422314	404827	395222
Feb	398669	420906	446650	422762	413949
Mar	403177	423526	431535	419710	408861
Apr	403898	429910	434735	415016	413031
May	409927	424312	432707	421279	416795
June	410312	432869	435973	422654	420286
July	414896	427467	428203	419947	412411
Aug	419255	429750	427453	416957	415370
Sept	430163	445103	440604	422201	432972
Oct	441428	446008	438502	426492	399130
Nov	424763	435397	433834	423264	399130
Dec	400071	412284	405284	391219	385570

Table 8 Ridership variations in different months and years

Table 8 shows ridership variations in different months and years. It is clear that the year 2018 has seen the most decline because the line's slope is more as compared to the other years.

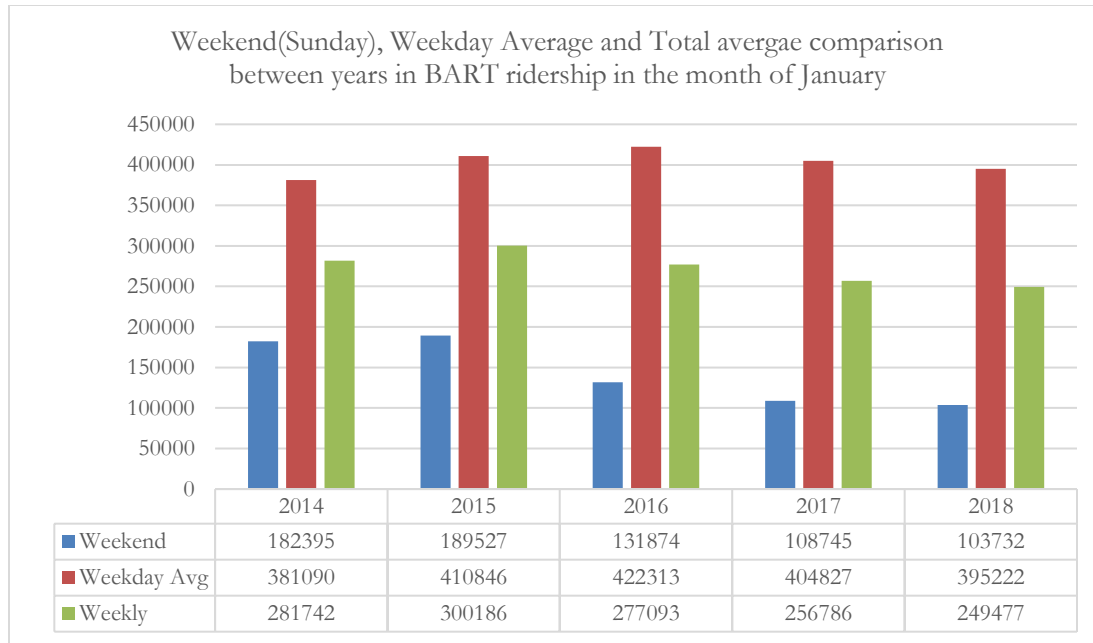


Figure 9 Ridership in January in between 2014-18

Figure 12 is representing the ridership variations in January in the years between 2014 and 2018.

BART Ridership Statistical Analysis and Findings

BART ridership data is vast and to make a direct comparison, the years 2017 and 2018 were chosen, like Caltrain. Ridership count of the people who enter at the endpoints which are Embarcadero and Millbrae respectively was taken into consideration.

Overall, the BART ridership showed a steady decrease from the year 2017 to 2018. The mean of riders getting into BART at Embarcadero in 2017 was 10725.89 which reduced to 10674.76 for the year 2018. For passengers boarding BART at Millbrae, the number reduced to 1700.60 in 2018 from 1748.30 which was observed in 2017. This estimation indicated the relevance of this analysis in the context of the thesis study. Median numbers for this same analysis looked as follows:

Month and Year	The median number of passengers entering at Embarcadero	The median number of passengers entering at Millbrae
2017	10231.0	425.5
2018	10140.5	386.0

Next, passengers entering at Millbrae for 2018 are considered for further analysis. From the data given by BART, most of the commuters preferred to get off either at Embarcadero or Montgomery, which is rational as these are the two most popular stations and are near to tourist locations and most importantly, office locations.

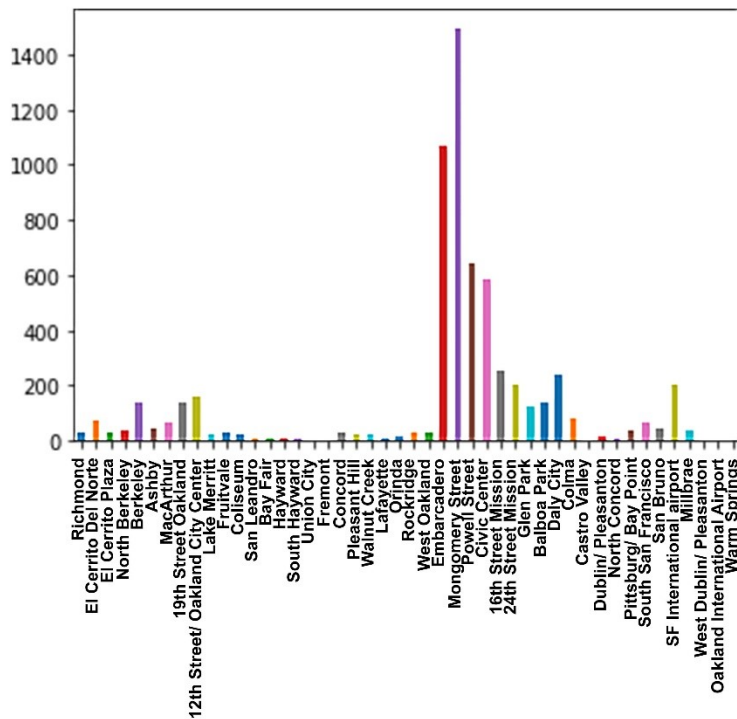


Figure 10 2018 graph depicting ridership in different stations.

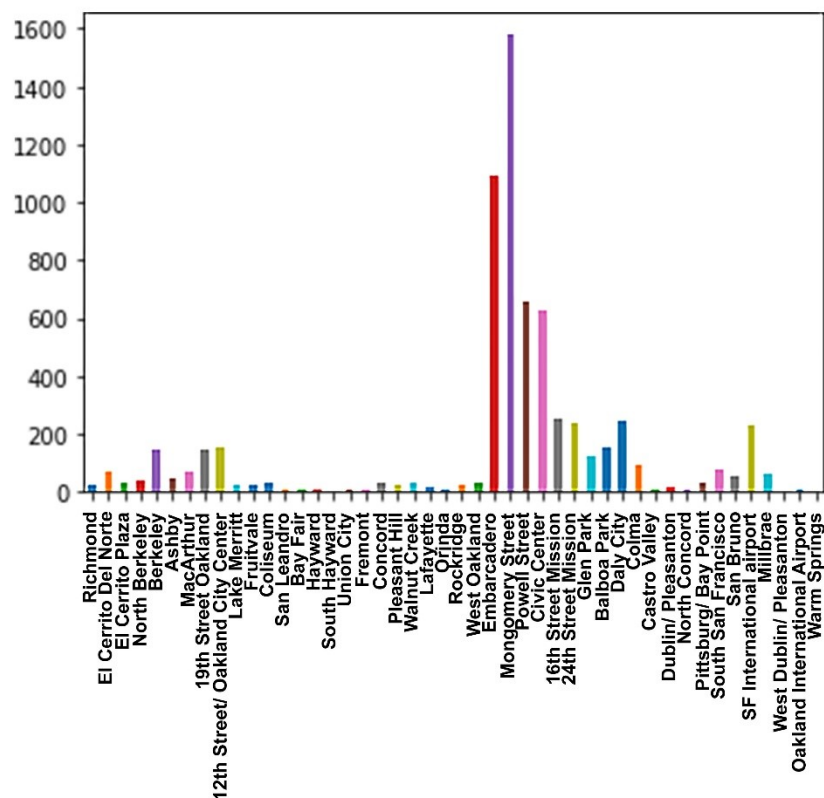


Figure 11. The ridership information of 2017 showed similar ridership trend. The total number of enteries and exits were higher in this case.

After that, the percentage reduction in several passengers boarding at Millbrae down at different stations in San Francisco and Peninsula area from 2017 to 2018 is calculated. Table shows the values that were recorded.

End Station	Number of Passengers in 2018	Number of passengers in 2017	Percentage reduction
Embarcadero	13237	13284	-0.35
Montgomery Street	18394	18110	-1.56
Powell Street	8058	8234	-2.13
Civic Center	7386	7863	-5.74
16 th Street	3021	3071	-1.62
24 th Street	2622	2742	-4.37
Glen Park	1572	1601	-1.81
Balboa Park	1704	1873	-0.90

Daly City	3196	3162	-0.10
Colma	1072	1146	-6.45
South SF	814	846	-3.78
San Bruno	585	665	-12.03

Table 9 Ridership comparison between January 2017 and January 2018: People are boarding at Millbrae. Source: BART ridership information

Table 9 shows that almost all the changes are reductions, except except a few. This observation persisted when the direction was changed and when Embarcadero was considered as an entry station:

End Station	Number of passengers in 2018	Number of Passengers in 2017	Passenger reduction
Montgomery Street	1755	1802	-2.60
Powell Street	9202	9447	-2.59
Civic Center	7474	7596	-1.60
16 th Street	13864	14121	-1.81
24 th Street	18890	18616	-1.47
Glen Park	13570	13422	1.10
Balboa park	16407	15640	4.90
Daly City	15524	14905	4.15
Colma	10223	10073	1.48
South SF	7486	7601	-1.51
San Bruno	7639	7640	-0.01
Millbrae	12360	12519	-1.27

Table 10 Table 5 Ridership comparison between January 2017 and January 2018: People are boarding at Embarcadero. Source: BART ridership information

After performing BART analysis, similar Python coded analysis was performed on Caltrain data to make direct ridership comparison. Caltrain data used was an annual ridership data for the years 2017 and 2018, and it had values for several passengers on board for every station. Only one route that is Millbrae to San Francisco was considered to make a comparison between Caltrain and BART along this route.

A mean number of passengers on board for all stations in the year 2017 was 11904 passengers per annum, which increased to 12322 in the year 2018, suggesting an upward trend in the ridership count. This trend was also seen in the median which increased from 15249 in 2017 to 15593 passengers per annum in 2018. Also, the noteworthy fact was that almost all San Francisco stations had more than a mean number of passengers onboard both in the year 2017 and 2018.

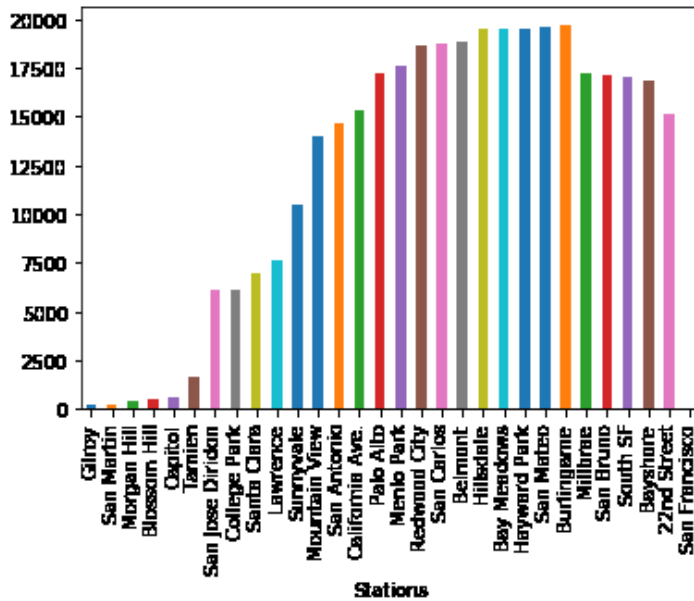


Table 11 Caltrain ridership analysis Year 2017. Source: Caltrain ridership information

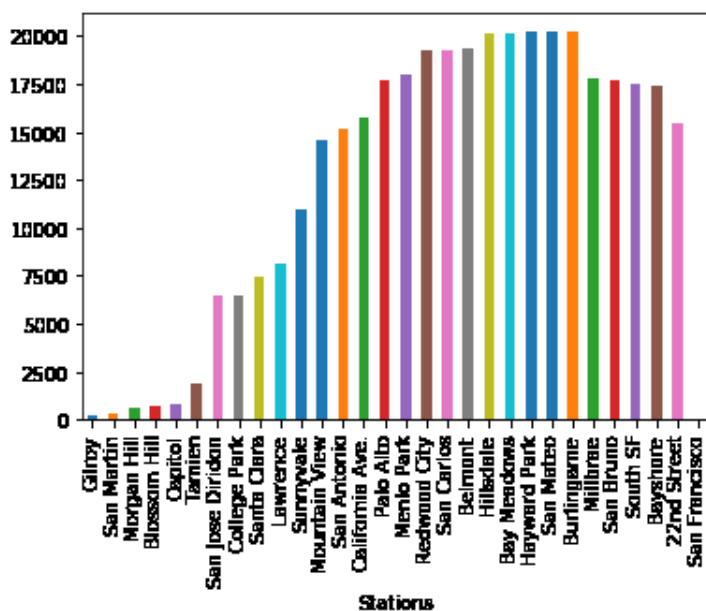


Table 12 Caltrain ridership analysis Year 2018. Source: Caltrain ridership information

The slope steadily increases until San Mateo and Burlingame and then suddenly starts reducing after that, suggesting that many passengers start getting down after Millbrae. Although, despite that, close to 15000 people are on board on 22nd street and get off at last station, which is San Francisco, underlining the fact that Caltrain is indeed popular as an SF commuting option.

Similar to BART analysis, the percentage change in several passengers on board annually from the year 2017 to 2018 are calculated. The table below shows the changes and percentages from the analysis respectively.

Station	Passengers in 2017	Passengers in 2018	Percentage change
Millbrae	17294	17773	2.94%
San Bruno	17099	17651	3.13%
South SF	17014	17499	2.77%
Bayshore	16874	17352	2.75%
22 nd street	15156	15456	1.94%

Table 13 Changes in ridership percentages in the San Francisco region

Table 13 shows a steady increase in several passengers for all stations, indicating that even if BART is not having enough riders in the Peninsula region, Caltrain indeed has a better ridership count.

GIS Analysis for the stations

Census blocks with more than 75,000 population are selected. Buffers of half mile distances are drawn around the stations. Those stations are considered which have the selected census blocks in them

Figure 12 GIS analysis for station selection

5.2.2 Uber and BART

The map in Figure 10 shows different BART routes in the Bay Area with population densities of the blocks being categorized as different colors as shown. The endpoints of the stations are Antioch, Daly City in the West Bay, Pleasanton in the East Bay and Warm Springs in the South East.

The map shows highlighted buffer zones which have blocks with population densities greater than 75000 within them and the half-mile buffer that is indicated.

After careful analysis, the following routes are selected for the study:

1. Fremont to Pleasanton
2. Pleasanton to Concord
3. Concord to Berkeley
4. Connectivity of the different regions of the Bay to San Francisco
 - i. Fremont to Embarcadero
 - ii. Pleasanton to Embarcadero
 - iii. Concord to Embarcadero
 - iv. Berkeley to Embarcadero

At most the regions in Bay Area, Uber supports various options. Different options as described by Uber are given table 14 below.

S.No	Service Type	Description
1	UberX	Normal private taxi
2	UberXL	Bigger taxi with up to six seats
3	Uber Black	Luxury ride with professional drivers
4	Uber Black SUV	Luxury ride for six people with professional drivers
5	Assist	A specialized assistant from certified drivers
6	Uber WAV	Wheelchair accessible vehicles
7	Uber Pool	Shared ride
8	Uber Express	Shared ride with small walk

Table 14 Different services provided by Uber

For making a direct comparison between different BART station prices, BART stations as pickup and drop off locations are considered for calculations and results were following for different routes.

Note that analysis is performed during peak hours:

Route	UberX	UberXL	Uber Black	Uber Black SUV	Assist	Uber WAV	Uber Pool	Uber Express Pool
Fremont-Pleasanton	\$23-29	\$33-40	\$79-98	\$95-118	\$23-29	\$23-29	\$14-18	\$7-10
Pleasanton-Concord	\$28-33	\$41-51	\$97-120	\$116-143	\$28-35	\$28-35	\$19-25	\$10-12
Concord-Berkley	\$22-28	\$37-46	\$88-108	\$105-129	\$22-28	\$22-28	\$15-20	\$8-10
Fremont-Embarcadero	\$39-48	\$64-79	\$145-179	\$170-209	\$39-48	\$39-48	\$30-38	\$24-30
Pleasanton-Embarcadero	\$43-54	\$62-77	\$139-171	\$164-201	\$43-54	\$43-54	\$29-37	\$20-25
Concord-Embarcadero	\$35-44	\$53-65	\$118-145	\$139-171	\$35-44	\$35-44	\$32-44	\$12-15
Berkley-Embarcadero	\$22-27	\$29-36	\$61-76	\$74-92	\$22-27	\$22-27	\$11-15	\$10-12

Table 15 Costs derived for a variety of services provided by Uber API for different routes

As seen in table 15, Uber offers a variety of comfort rides, with Uber Express Pool as the cheapest option available. For BART during the above routes, prices are given in table 16.

Route	Price	Transfer required at
Fremont-Pleasanton	\$4.95 one way, \$9.90 both ways	Bay Fair
Pleasanton-Concord	\$6.45 one way, \$9.90 both ways	Bay Fair, 19 th street Oakland
Concord-Berkley	\$4.10 one way, \$8.20 both ways	19 th street Oakland
Fremont-Embarcadero	\$6.30 one way, \$12.60 both ways	
Pleasanton-Embarcadero	\$6.30 one way, \$12.60 both ways	
Concord-Embarcadero	\$5.95 one way, \$11.90 both ways	
Berkley-Embarcadero	\$3.95 one way, \$7.90 one way	12 th street Oakland

Table 16 Comparison table for BART and Uber

From table 16, it can be concluded that BART is a much cheaper option than Uber when BART station is nearby. Although, when a BART station is far, then Uber becomes way much cost effective, as you might need to take Uber as a last mile transport alongside BART.

Also, Uber is quicker than BART and BART might be slow on weekends due to repair and due to lesser frequency. Another thing to note here is that Uber price is variable and can go down and even become lesser than some occasions or can become high due to the price surge.

People also find Uber much safer than BART, as it is more reliable and has many in-app securities features. For example, a rider can share their ride details with his or her friends or family friends as long as they have an Uber app. BART doesn't provide many security options within trains, except helplines.

Uber vs. BART timing analysis

After pricing analysis in the above section, Uber vs. BART timing analysis for pickup at 9 am on Monday at given routes are calculated. For simplicity, timing analysis for only three types of Ubers: UberX, UberExpress, and UberPool are done as rest of them will take some time as of UberX.

Route	The time required for UberX	The time required for UberPool	The time required for Uberexpress
Fremont-Pleasanton	51 minutes	82 minutes max	91 minutes max
Pleasanton-Concord	39 minutes	57 minutes max	64 minutes max
Concord-Berkley	34 minutes	57 minutes max	61 minutes max
Fremont-Embarcadero	51 minutes	93 minutes max	104 minutes max
Pleasanton-Embarcadero	46 minutes	82 minutes max	92 minutes max
Concord-Embarcadero	43 minutes	64 minutes max	75 minutes max
Berkley-Embarcadero	23 minutes	43 minutes max	42 minutes max

Table 17 This shows time differences with different services of Uber

For BART the estimation of time required is as follows:

Route	Time
Fremont-Pleasanton	38 minutes (Orange -> Blue)
Pleasanton-Concord	85 minutes (Blue-> Orange-> Yellow)
Concord-Berkley	32 minutes (Orange-> Yellow)
Fremont-Embarcadero	46 minutes (Green)
Pleasanton-Embarcadero	46 minutes (Blue)
Concord-Embarcadero	43 minutes (Yellow)
Berkley- Embarcadero	20 minutes (Orange-> Yellow)

Table 18 Time taken for BART for the same routes considered by Uber

5.2.3 Carpooling

For Carpooling, different routes are selected based on the carpooling opportunities available in the Bay Area. According to traffic.511.org, Scoop, Waze and 511 Carpooling services are the major carpooling services. The 511 is more established in the North Eastern part of California and San Francisco according to their website. Hence, the first route selected is Oakland to San Francisco. Due to the same reason and because Berkeley lies on the BART route, Berkeley to San Francisco is selected. The third route considered is Fremont to Pleasanton as they are both the ends of BART stations and Mountain View lies in between them. Finally, Warm Springs to Millbrae is selected as they are the endpoints of BART in the peninsula region.

	Carpool		BART	
Route	Price	Time	Price	Time
Oakland→ San Francisco	9\$	20 Mins	4\$	14 Mins
Berkeley→ San Francisco	9\$	24 Mins	4.7\$	50 Mins
Fremont→ Pleasanton	6\$	30 Mins	6.05\$	52 Mins
Warm Springs→ Millbrae	9\$	42 Mins	8.5\$	2 hrs

Table 19 Comparison between Carpool and BART

From the above observations, we can see that only for the route Oakland to San Francisco, BART is a better option than Carpool. The driving time is also more in the case of this route is because the

vehicles have to go through the San Francisco- Oakland Bay bridge only to reach San Francisco from East Bay. Other routes would add more miles to the route.

Chapter 6. Discussions

6. 1. BART is neither bad nor good

According to Cabanatuan, the decline in BART ridership is due to lack of security, reliability, and overcrowding during peak hours. (Cabanatuan, 2017a) The survey (Appendix 7) with the commuters mentioned other problems as well. Fifteen out of seventy-eight commuters complained that BART was not connected to all regions of the Bay Area. This limited the commuters to use the service for going to their offices. Thirteen subjects used the service exclusively when they were traveling to the San Francisco region among the seventy-eight commuters who took the survey. The commuters could avoid traffic and finding a location for parking for their cars. Although BART is known to not having enough parking spaces near its stations according to Brock (Brock, 2019), it was reducing the number of cars that could have come to San Francisco region indirectly as mentioned by the subjects.

The other notable benefits of BART that were analyzed through quantitative methods are that it is cheaper than other modes of transportation in some regions of the Bay Area although Scott Morris indicated that cost of tickets rose as the ridership declined (Morris, 2017)³⁴. BART is the only transportation network that connects the majority of the East Bay with the San Francisco region. Although traveling long distances tickets are costlier in BART when compared to short distances, short distances tickets are much cheaper when compared with Caltrain and even some carpool

³⁴ Morris, S. (2017, May 30). Has BART Overexpanded? Retrieved March 24, 2019, from <http://www.oaklandmagazine.com/June-2017/Has-BART-Overexpanded/>

services. BART is also offering incentives to young people who are under 18 years of age as well as physically disabled people by making tickets available for them at just 1.5 \$ anywhere. BART coaches have space dedicated for bikes which allow the rider to reach their destination from BART station by it. As Brock mentions, (Brock, 2019) car-poolers have a better chance of signing up for a parking spot near a BART station. The possibility for easy sign up itself is an incentive for people for making them use share cars with their neighbors or colleagues at their workplace.

6.2 Understanding BART and Caltrain further

The ridership calculations between BART and Caltrain are done in this study to understand the comments made by Alon Levy and JLL's research. (Bosselman, 2018)³⁵The results suggest the same as what Levy has mentioned. There is a rise in ridership numbers in Caltrain and decrease in BART for the same routes between the years 2016 and 2018.

This sudden change in ridership although BART is considered to be much faster than Caltrain is because BART and Caltrain are significantly different in the relationship that they have different pricing models. On the one hand, BART uses mile-based pricing model (further you go, more you pay), Caltrain uses zoning-based pricing model, in which it divides the whole Caltrain route into different zones.

As shown in figure 11 and 12, Caltrain is divided into 6 zones with different traveling ticket costs. According to the zoning division, if someone were traveling from San Francisco to Gilroy, he or she would need to pay \$15.00 for a one-way trip. On the other hand, traveling from Warm Springs to

³⁵ Bosselman, A. (2018, June 18). Bay Area subway and rail costs: Why are they among the highest in the world? Retrieved February 22, 2019, from Curbed SF website: <https://sf.curbed.com/2018/6/18/17464616/bay-area-subway-train-rail-costs-price-bart-muni>

Millbrae which are the ends point of BART in peninsula and East bay costs \$8.00 only. Also, traveling from warm springs to Richmond (southmost peak to Northmost peak) costs \$5.90 for a one-way trip. Some trips of BART are cheaper than that of Caltrain. For example, the ticket from San Francisco to Millbrae costs \$4.75 by BART, but it costs \$6.00 by Caltrain.



Figure 13 Zone divisions of Caltrain route.

Ticket Type*	How to Buy	Travel within					
		1 Zone	2 Zones	3 Zones	4 Zones	5 Zones	6 Zones
One Way	Ticket Machine	\$3.75	\$6.00	\$8.25	\$10.50	\$12.75	\$15.00
	Clipper Card	\$3.20	\$5.45	\$7.70	\$9.95	\$12.20	\$14.45
Day Pass+	Ticket Machine	\$7.50	\$12.00	\$16.50	\$21.00	\$25.50	\$30.00
Zone Upgrade	Ticket Machine	\$2.25 per zone					
Monthly Pass++	Clipper Card	\$96.00	\$163.50	\$231.00	\$298.50	\$366.00	\$433.50

Figure 14 Zone wise pricing of Caltrain tickets

Now, even if one station towards San Francisco, San Bruno for example, the ticket price of Caltrain drops to \$3.75 whereas BART remains at \$4.40. In other words, Caltrain's pricing model which is similar to New York's MTA pricing subway model (no matter where you go, pay the almost same price), can prove cheaper in some cases. The lesser costs could have been the reason for Millbrae station not functioning to its expectation as mentioned by Bosselman (Bosselman, 2018).

6.3 Locations of stations, last mile transport and other facilities of Caltrain

As seen in the Caltrain map in Figure 11 and BART map in Figure 2 previously, BART goes a little western region of San Francisco before entering the south in Peninsula, whereas Caltrain stations are situated on more Eastern side of San Francisco and the Peninsula regions. The location essentially allows BART to explore western mid-San Francisco area more, which is untapped due to lack of last mile connections. Also, BART provides direct connectivity to San Francisco airport, something that Caltrain lacks to provide, which as reported in the literature search had been a politicized action by the senator when it was constructed. (Dawid, 2017)³⁶ Although, where Caltrain's ridership is more, it is only in some specific routes. It provides connectivity until South bay and provides a connection to

³⁶ Dawid, I. (2017, July 16). Why was BART's Ridership Forecast for Millbrae Station So Wildly Off-Base? Retrieved March 24, 2019, from Planetizen - Urban Planning News, Jobs, and Education website: <https://www.planetizen.com/node/93755/why-was-barts-ridership-forecast-millbrae-station-so-wildly-base>

BART station through Millbrae. Hence, Millbrae should have been very beneficial for the commuters who would want to travel in western parts of the San Francisco region although Bosselman in the literature review had commented otherwise (Bosselman, 2018).

The important observation from the further analysis of Caltrain system while identifying its prices and why it had better ridership compared to BART was that unlike BART, Caltrain provides shuttle services that provide last mile service to the commuters. The service is free of cost and connects the Caltrain stations to various tourist and central locations in San Francisco including Chinatown, Civic Center and popular financial district of San Francisco. This shuttle service expands from almost all stations of Caltrain and users subscribe to the alerts through cellphones. (Caltrain, 2017) The mentioned factors could also be the reasons for more ridership in Caltrain than in BART. As mentioned by Levy, the construction of Millbrae station with three tracks dedicated to BART with only one track for Caltrain signifies how BART is trying to take over the old public transportation system in the San Francisco region rather than benefitting the commuters. (Bosselman, 2018)

6.4 Reasons for less usage of BART

Some of the drawbacks are lack of security, cleanliness and required several parking spaces as mentioned by Cabanatuan (Cabanatuan, 2017a). Apart from that, the commuters have expressed that BART does not have express services resulting in no faster movement to places within the Bay Area. Many subjects in the survey tended to use the service only when it was okay to be late to their workplace. Three of the commuters said that they used BART when they were sick which means that BART is not used as the first choice of transportation while the commuters are traveling to their workplace.

Although BART's ridership is declining according to the report of SFGate in 2017 (Cabanatuan, 2017a), ironically, the commuters still complain that during the peak hours, BART is very crowded. Hence, it is necessary that the frequency has to be increased at least the main stations of the Bay Area during the peak hours. Unlike, MTA of the New York city, no free transfer system available to the commuters. This issue is resolved for the commuters of Caltrain. Although some routes of Caltrain is costlier than BART, it is more preferred by the commuters only because of its free transfer system. Also, the BART app is not updated and needs more changes for being more commuter friendly than what is currently. BART also uses Twitter to convey the information about its delays, schedules and other information to its users. These varied systems and not updated information cause more confusion among the commuters according to the survey.

6.5 Positives that other modes of transportation bring

As expressed by Darrow, ridesharing apps such as Uber and Lyft have a drastic impact on BART ridership. (Darrow, 2017) Uber is not just popular in the Bay Area but all around the world. A tourist would choose to travel by Uber rather than by BART as the app, and the pricing model of it is very user-friendly. The different options available – Uber Express, pool, and others give the option to people to choose from according to their needs and what they can pay. Although Ariana Marshall has expressed that vehicles delays on the major roads in the Bay Area are due to these new services (Marshall, 2018), there are also other benefits due to these services. It has increased employment rates among the individuals who are willing to earn by driving. Some interviewees chose Uber or Lyft over BART because they felt it was faster and safer means of transportation than BART for them. Commuters could avail the possibility of sharing the ride information with their friends or family members as long as they had the Uber app. But, it is true that some of the trips involve just one passenger as expressed by Siddiqui in his report. (Siddiqui, 2018) It is also true that

once individuals start using the cabs or taxi, then they try not to use public transit again as that becomes the service is generally provided right next to the individual's home rather than at a distance as finding out by the students from the University of California. (Regina & Mishra, 2017) Some commuters preferred carpooling over BART as it was a cab service and also cheap. The same people also preferred Uber or Lyft over BART as it was more convenient than reaching to the location of BART station although it meant spending more. One of the reasons for preferring this is because carpooling was their daily method of going to their workplace while taking Uber was only at those times when they did not find a match through carpool apps.

As said by Helft, the Carpool service Scoop caters to employees. (Helft, 2017) The carpooling services have proven to be a great way to network and socialize with people in the same office. One of the Scoop drivers said that he got a great opportunity to talk with the people who were from the same office with whom he had never talked before which gave him the chance to discuss better restaurants, festivals, functions, and shops in their locality which was a way to acknowledge more about their locality.

At many regions, they provide the cheapest and easy mode of transportation as the driver directly comes to the rider's home location to pick them up and drop them at their office. This system has brought new culture for the daily routine travel for both the parties.

Chapter 7. Conclusions

According to a study conducted in 2017, the San Francisco city was ranked as the fifth worst city in the world and third-worst in the United States concerning its traffic congestion. (Brock & Suratos, 2018) People in the region spend at least 12% of their driving time in dealing with traffic-related congestion (Brock & Suratos, 2018) which is happening due to the unplanned public transit system in the Bay Area. The importance of transportation planning to make better transportation services and developments around a transit hub will only increase in the coming years.

BART's various extension projects are aimed at making the Bay Area more connected so that the residents can use the service for traveling to their workplace every day. This study depicts the other modes of transportation that have become better alternatives with variations in pricing, ticketing, time factors, and convenience. Hence, integrating BART with other public transportation modes would benefit the Bay Area tremendously. However, creating a policy to integrate the different modes of transport mentioned in this study has its limitations. This section identifies the changes that should be made to BART to make it more efficient as well as the issues that should be addressed in the long term.

7.1. Limitations of the Study

This study has some limitations. First, in the qualitative analysis, only 78 commuters were surveyed in random stations of the Bay Area. These are not an exact representation of the existing population of the Bay Area. Social factors such as ethnicity and income levels were not considered when these interviews were done. There is a high chance that what could be costly for one individual may not have been for another considering the social disparities in California. Not all commuters answered all questions. This may have resulted in errors in the observations made regarding the field of work,

age group and if they owned a car or not. The interviews were taken in December. Hence, the study represents the observations in the winter in the California Bay Area.

Only ten carpool drivers and riders were interviewed to understand why they used carpool apps. This definitely does not represent the entire driver- rider population of the Bay Area. This analysis is a part of qualitative analysis in this research and there could be many more reasons to why people used carpooling services than the ones mentioned in this study.

7.2. Recommendations

Considering the limitations that BART is contending with, the goals and recommendations could be shaped into three categories as physical-infrastructure developments, community-data related developments and integration-long term developments.

Physical and infrastructure Developments

The research in this study suggested that BART lacks security and maintenance. It is important to make commuters feel they are safe while they are traveling on BART. The BART authorities should employ more workers for this purpose. An average BART's worker earns \$4000 per month according to BART's factsheet on their website(2018_BART Factsheet, 2018). An average ride cost of a rider is \$4.5. So, for every hundred more commuters, one employee can be employed by BART. An addition of at least 1,000 security personal which would cost approximately 4.5 million at different stations can solve this issue. As people feel safe, they would start using the service more frequently especially during the nights.

Increasing the frequency of the trains during peak hours can help in managing the crowd during peak times. This solution has been mentioned by expert Cabanatuan(Cabanatuan, 2017a) but was not implemented as this meant the addition of more trains. But, BART is currently planning to add new train systems into its fleet that will be implemented only by 2026 (BART, 2019). It costs BART \$1.15 billion, and the money for this purpose is taken from the commuters through their ticket payments. As many commuters in the research have complained about its price, this step can further deteriorate the ridership numbers. As Uber's express pool service has made cab affordable to many, BART has to make its tickets should cost at least half the price of Uber's ride to improve its ridership. I believe private companies should invest in BART for this purpose as they would be benefitted if they subsidize tickets of their employees using BART and also let them become sponsors for this improvement in BART. Facebook is building its new office in the East Bay. (Brasuell, 2017) Hence, companies like facebook and similar private companies can invest in BART's improvements for the benefit of its employees. Partnering with companies will result in less pressure on BART. As the expenditure would be distributed among both the parties, it would cost much less than \$1.15 billion for BART.

Community and data-related Developments

Commuters should be incentivized based on their usage of BART. As a card with a chip is used for ticketing purpose of every ride, it can also record the number of times a commuter has used the service in a week. If a commuter has used it more than a certain number of rides, BART can reduce or make a ride free of cost. This would only cost an average of \$4.5 per person per week for a single rider. As an average of 429,000 riders commute per week by BART, it will have an expenditure of \$1,930,500 per week but this would be compensated by the amount gained due to the regular riding of the commuters to avail this incentive itself.

BART has a rich history. It can organize events and attract people to attend them. It can create a culture like New York Subway has created. Addition of BART related quotes, posters, slogans, and short poems in the stations and the trains can make commuters feel more interested in traveling by BART. Much like Niles canyon railway, BART can start their version of running theme-based train, to spread the messages and make people look at BART with a different point of view. Volunteers run Niles Canyon, and it's not costly. (Niles Canyon Rail, 2019) BART also can make the theme-based train service exclusively volunteer based.

Improvements to the existing BART app are also needed. As data about other services such as Caltrain, Muni, AC transit and ACE are open-sourced, BART can create an algorithm to suggest its commuters most efficient routes to their destinations that involve transfers with the mentioned transit services. This can be devised from the existing software engineers that BART already has and the changes can be done to the current app or BART can hire five software engineers, given the salary of one is \$100,000-\$150,000, the entire cost would be less than \$700,000. They can also hire consultants which will make this one time payment.

Transit Integration and long-term considerations

A long-term goal of BART should be to spread awareness about its sustainable service in comparison with private car ownership. Schools and colleges in the Bay Area should spread the importance of usage of BART to the younger generation. Environmental aspects and reaching their destination in lesser time should also be a priority while recommending BART.

BART should partner with the alternate transit agencies- Caltrain, Carpooling services, rideshare services. All these should have a standardized ticketing system that can be controlled with one single mobile app or a transportation card. This was never exercised before. It is obvious that Uber and Carpool services wouldn't be willing to join with a public transit service unless they are benefitted decently, incentives should be provided to the drivers who are willing to work with BART. This can vary from \$25-\$100 depending on the number pick-ups that a driver is willing to do from the BART stations. Private companies have already formed partnerships with Carpooling agencies for making it easy for their employees to reach their office on time rather than depending on uncertain public transportation. Companies like Google pay their employees for Uber costs, so expenditure on that is no longer a restriction for employers to come to the office. Companies should also join with BART. BART can also connect with VTA from Milpitas and incentivize riders. Efforts are already being made in this direction. (VTA BART, 2018) BART should offer more last mile transports. Investigate and implement the possibility of having more Go bike like public usage bicycle rentals on the East Bay (BART, 2019a). Such tranfers can be the same cost as average ticket prices of BART, VTA or Go Bike services respectively.

Ultimately, BART's goal is to serve its commuters a safe, clean, cheap and efficient rides to their destinations. This research has suggested various ways of improving the existing condition of BART. Considering its past, it should focus more on its maintenance over extension and in collaboration with other transit systems over competing with them to better serve its commuters.

Appendices

Appendix 1: BART Commuter Survey

1. What is your age?
 - ☐ Under 18
 - ☐ 18-24
 - ☐ 25-45
 - ☐ Above 45
2. In which field do you work
 - ☐ Technology
 - ☐ Construction and Design
 - ☐ Medicine
 - ☐ Retail
 - ☐ Other
3. Where is your workplace?
4. Where is your home?
5. Do you/family member own a car? If yes, why are you still traveling by BART?
6. Which mode of transportation do you think is the best mode to reach your office?
 - ☐ BART
 - ☐ Own Car
 - ☐ Carpool
 - ☐ Other
7. When do you tend to use BART?

8. What do you think is the biggest drawback of BART?

Appendix 2: BART Officials Questionnaire

1. What is your job title?
2. From when are you working for BART?
3. Do you think that more people use BART now than in previous days? If yes, what changes do you think led to that? If no, please explain your observations.
4. Are there any strategies that BART is coming up within the recent future to increase its ridership? If so, can you please name some of the strategies?
5. Is BART planning to add more stations? If yes, which counties/places are considered?
6. Do you believe people are well aware of facilities, security helplines, and BART mechanisms? What are the most frequent questions or problems that the commuters bring to you every day?

Appendix 3: Carpool Driver Questionnaire

1. What is the source and destination of your ride?
2. What motivates you to use carpool driving app instead of driving alone?
3. Would you prefer more if you have to pick people up from a centralized location instead of picking up from their homes?
4. Considering the traffic during rush hours, why don't you switch to the use of public transport and BART?
5. What is the reason for your answer to question 2?

Appendix 4: Carpool rider Questionnaire

1. Do you think Carpooling is a better mode of transport over BART or Uber? Why?

2. Is it possible to reach your destination using BART? If yes what is the major reason for you to use carpooling instead?
3. If you don't get a Carpool match, what is the second mode of transport you would travel by?
4. Would you be willing to walk a little and then get picked up from a centralized location instead of your home, if Carpool apps offer you such an option at a lower price?

Appendix 5: Python code comparing BART and Caltrain

```
import numpy as np
import pandas as pd
import seaborn as sns
import matplotlib.pyplot as plt
%matplotlib inline

#1. First comparing number of passengers in BART and Caltrain during the
weekdays between
# common part:
#For BART: Embarcadero and Milbrae. BART data is monthly. Use Jan 2018, Jan
2017
#For Caltrain: SF and Milbrae. Caltrain data is annual. Use 2018, 2017.

BART_18 = pd.read_excel ("Ridership_201801.xlsx", sheetname = "Weekday OD")
BART_17 = pd.read_excel ("Ridership_201701.xlsx", sheetname = "Weekday OD")

CALTRAIN_18 = pd.read_excel ("2018_caltrain.xlsx", sheetname = "Sheet_1")
CALTRAIN_17 = pd.read_excel ("2017_caltrain.xlsx", sheetname = "Sheet_1")

#print (BART_17.head)
#we need column: MB
#we need rows: EM, MT, PL, CC, 16, 24, GP, BP, DC, CM, SS, SB, MB

BART_18 = BART_18.filter (items = ['Station', 'EM', 'MB'])
BART_17 = BART_17.filter (items = ['Station', 'EM', 'MB' ])

print (BART_18)
print ("For 2018")
print (BART_17)
print ("For 2017")

#drop the total row here
BART_18.drop(BART_18.tail(1).index,inplace=True)
BART_17.drop(BART_17.tail(1).index,inplace=True)

#1. Finding mean for BART_18 and BART_17 and plotting graphs
#compute means for both the columns for both the years
MeanB_18_EM = BART_18["EM"].mean()
MeanB_18_MB = BART_18["MB"].mean()
MeanB_17_MB = BART_17["MB"].mean()
MeanB_17_EM = BART_17["EM"].mean()
```

```

print(MeanB_18_EM)
print(MeanB_18_MB)

print(MeanB_17_EM)
print(MeanB_17_MB)

print (BART_18.median())
print (BART_17.median())

#bar graph for 2018
BART_18.plot (x= "Station", y = "MB", kind="bar")
plt.show()

#bar graph for 2017
BART_17.plot (x= "Station", y = "MB", kind="bar")
plt.show()

#compute percentage decrease from year 2017 to 2018 for route EM-> MB
#row number 25 is Embercadero
diff = BART_18.loc[25, "MB"] - BART_17.loc[25 , "MB"]
per = diff/BART_18.loc [25 , "MB"]
per = per*100

print(per)

#row number 26 is MT
diff = BART_18.loc[26, "MB"] - BART_17.loc[26 , "MB"]
per = diff/BART_18.loc [26 , "MB"]
per = per*100

print(per)

def cal (x):
    diff = BART_18.loc[x, "MB"] - BART_17.loc[x , "MB"]
    per = diff/BART_18.loc [x , "MB"]
    per = per*100
    return per

def cal (x,y):
    diff = BART_18.loc[x, y] - BART_17.loc[x , y]
    per = diff/BART_18.loc [x , y]
    per = per*100
    return per

i = 0
while i<17:
    print("starting at Milbrae")
    result1 = cal ((i+25), "MB")
    print(result1)
    print("starting at Embercadero")
    result2 = cal ((i+26), "EM")
    print(result2)
    i = i+1

```

```

#per_diff = diff_MB_18/BART_18["MB"]
#print(per_diff)
#per_diff = per_diff * 100
#print(per_diff)

#2. Doing similar analysis for Caltrain, in direction towards San Fransisco
#Total_18 = CALTRAIN_18.columns [141]
#Total_17 = CALTRAIN_17.columns [141]
#print(Total_18)
#print(Total_17)

#print(CALTRAIN_18.head())
caltrain_18_col = CALTRAIN_18[CALTRAIN_18.columns[-1]]
caltrain_18_stations = CALTRAIN_18["Passengers"]
print(caltrain_18_stations)
print(caltrain_18_col)

caltrain_18 = pd.DataFrame(
    {'Stations': caltrain_18_stations,
     'on_board': caltrain_18_col
    })

caltrain_18.drop(caltrain_18.tail(1).index,inplace=True)
caltrain_18 = caltrain_18.drop(caltrain_18.index[0])
print(caltrain_18)

caltrain_17_col = CALTRAIN_17[CALTRAIN_17.columns[-1]]
caltrain_17_stations = CALTRAIN_17["Passengers"]
print(caltrain_17_stations)
print(caltrain_17_col)

caltrain_17 = pd.DataFrame(
    {'Stations': caltrain_17_stations,
     'on_board': caltrain_17_col
    })

caltrain_17.drop(caltrain_17.tail(1).index,inplace=True)
caltrain_17 = caltrain_17.drop(caltrain_17.index[0])
print(caltrain_17)

#mean number of passengers in all trains at every station
#find percentage difference
diff = caltrain_18["on_board"].astype(float) -
caltrain_17["on_board"].astype(float)
per_diff = diff / caltrain_18["on_board"].astype(float)
per_diff = per_diff * 100.00

print(per_diff)
pd_diff = pd.DataFrame(
    {'Stations': caltrain_17_stations,
     'difference': per_diff
    })

```



```

    })

print(pd_diff)
#plot the bar graph
#bar graph for 2018
caltrain_18.plot (x= "Stations", y = "on_board", kind="bar")
plt.show()

#bar graph for 2017
caltrain_17.plot (x= "Stations", y = "on_board", kind="bar")
plt.show()

Mean_caltrain_18 = caltrain_18["on_board"].mean()
Mean_caltrain_17 = caltrain_17["on_board"].mean()

print(Mean_caltrain_18)
print(Mean_caltrain_17)

print (caltrain_18["on_board"].median())
print (caltrain_17["on_board"].median())

```

Appendix 6: Python code analysing Uber prices through Uber API

```

#1. Fremont to Pleasanton
#2. Pleasanton to Concord
#3. Concord to Berkley
#4. Embarcadero to Fremont, Embarcadero to Pleasanton, Embarcadero to
Berkley, Embarcadero to Concord

from uber_rides.session import Session
from uber_rides.client import UberRidesClient
import requests

session = Session (server_token = "687Yu9KHZFDBBrfwUHJaE_vrVCVR23v_hxMPmAGR")
client = UberRidesClient(session)
credentials = session.oauth2credential

#1. Fremont-Pleasanton
response = client.get_products(37.557606, -121.975801)
products = response.json.get('products')

response = client.get_price_estimates(
    start_latitude=37.557606,
    start_longitude=-121.975801,
    end_latitude=37.701182,
    end_longitude=-121.897380,
    seat_count=1
)
estimate = response.json.get('prices')
print(estimate)

#BART is $4.95, one way, $9.90 both ways

```

```

#2. Pleasanton-Concord
response = client.get_products(37.701182, -121.897380)
products = response.json.get('products')

response = client.get_price_estimates(
    start_latitude=37.701182,
    start_longitude=-121.897380,
    end_latitude=37.973872,
    end_longitude=-122.028945,
    seat_count=1
)
estimate = response.json.get('prices')
print(estimate)

#BART is $6.45 one way, $12.90 both ways

#3. Concord-Berkley
response = client.get_products(37.973872, -122.028945)
products = response.json.get('products')

response = client.get_price_estimates(
    start_latitude=37.973872,
    start_longitude=-122.028945,
    end_latitude=37.870601,
    end_longitude=-122.269606,
    seat_count=1
)
estimate = response.json.get('prices')
print(estimate)

#BART is $8.20 round trip, one way is $4.10

#4. Fremont-Embercadero
response = client.get_products(37.557606, -121.975801)
products = response.json.get('products')

response = client.get_price_estimates(
    start_latitude=37.557606,
    start_longitude=-121.975801,
    end_latitude=37.793155,
    end_longitude=-122.396691,
    seat_count=1
)
estimate = response.json.get('prices')
print(estimate)

#BART is $6.30 one way and $12.60 round trip

#5. Pleasanton-Embercadero
response = client.get_products(37.701182, -121.897380)
products = response.json.get('products')

response = client.get_price_estimates(
    start_latitude=37.701182,
    start_longitude=-121.897380,
    end_latitude=37.793155,

```

```

        end_longitude=-122.396691,
        seat_count=1
    )
    estimate = response.json.get('prices')
    print(estimate)

#BART is $6.30 one way and $12.60 round trip

#6. Concord-Embercadero
response = client.get_products(37.973872, -122.028945)
products = response.json.get('products')

response = client.get_price_estimates(
    start_latitude=37.973872,
    start_longitude=-122.028945,
    end_latitude=37.793155,
    end_longitude=-122.396691,
    seat_count=1
)
estimate = response.json.get('prices')
print(estimate)

#BART is $5.95 one way, round trip is $11.90

#7. Berkley-Embercadero
response = client.get_products(37.870601, -122.269606)
products = response.json.get('products')
response = client.get_price_estimates(
    start_latitude=37.870601,
    start_longitude=-122.269606,
    end_latitude=37.793155,
    end_longitude=-122.396691,
    seat_count=1
)

estimate = response.json.get('prices')
print(estimate)
#BART is $3.95 one way, round trip is $

```

Appendix 7: Commuter Survey results

S.N	Age	Field of Work	Workplace Location	Home Location	Car/No Car	Why Still Using BART	Best Mode choice	When do you use BART	Biggest Drawback According to you
1	18-24	Technology	Fremont	San Jose	Car	I travel when my route has BART station	Own Car	When I go to places that are on BART route	Connectivity
2	25-45	Technology	Sunnyvale	Fremont	Car	Lack of Parking in CA	Own Car	Might not find parking lot	Connectivity
3	25-45	Medicine	Oakland	Dublin	Car	Driving in traffic on 680 is much more difficult	BART	Going to office	Less Frequency

4	25-45	Technology	San Francisco	Fremont	Car	I travel on weekends or on holidays. It saves efforts of driving and parking in general.	Own Car	When I am going on weekends to SF or any other place.	Repairs and Less frequency
5	25-45	Technology	San Francisco	Hayward	Car	When no other option	Own Car	When no other option	Less Frequency
6	Above 45	Other	San Mateo	Fremont	Car	I hate driving in Traffic	BART	Traffic while driving	Security
7	25-45	Construction and Design	Pleasanton	Fremont	Car	Saves time	BART	Going to office	It is slower than other modes of transport
8	18-24	Technology	San Jose	Pleasanton	No Car	NA	Carpool	When I go to places that are on BART route	It is very costly
9	25-45	Technology	NA	San Jose	No Car	NA	Carpool	While going to SF	None
10	25-45	Technology	Fremont	Fremont	No Car	NA	Uber	While travelling on Vacation	Connectivity
11	18-24	Technology	San Jose	San Jose	No Car	NA	Other	Going to Fremont or SF	Number of BART Stations
12	25-45	Technology	San Jose	Campbell	No Car	NA	Carpool	Going to SF	Connectivity
13	18-24	Technology	San Francisco	Fremont	No Car	NA	BART	Going to office	Crowded during rush hours
14	18-24	Construction and Design	Pleasanton	Hayward	Car	It's easier. I don't have to drive	BART	Going to office	Everything
15	25-45	Technology	San Jose	Fremont	Car	To avoid traffic	Carpool	Going to office	Frequency is less
16	25-45	Technology	San Jose	Fremont	No car	NA	Carpool	When going to SF	Connectivity
17	25-45	Technology	Embarcadero	Ashby	No Car	NA	BART	Going to office	Unclean, Connectivity, Frequency
18	18-24	Technology	Cupertino	Milpitas	No Car	NA	Other	Never	NA
19	25-45	Technology	San Jose	Milpitas	No Car	I don't use it much	Own Car	To go to SF	Connectivity
20	25-45	Other	San Francisco	Berkely	No Car	NA	BART	Going to office	Maintenance, security
21	25-45	Technology	San Jose	San Jose	Car	To avoid parking and driving downtown	Carpool	When I feel parking will be a problem	Doesn't branch east west in san Francisco
22	25-45	Technology	San Jose	San Jose	Car	Its easier to go to SF	Own Car	Its easier to go to SF	Connectivity
23	25-45	Medicine	San Francisco	Fremont	Car	I don't go to work by BART	Own Car	When going into SF during major holidays such as New Year's eve or July 4th, where there is likely to be large crowds and limited parking spaces.	Not fast enough from Fremont to SF and often packed with no room to sit.
24	25-45	Technology	Mountain View	San Jose	Car	When going to SF	Own Car	Going to SF	Too much crowd
25	25-45	Technology	San Francisco	Union City	Car	No traffic in BART	BART	Going to office	Price
26	18-24	Other	San Francisco	Hayward	Car	Tuesday mornings	BART	All Tuesday mornings mostly	security, cleanliness
27	25-45	Technology	Oakland	Fremont	Car	No traffic in BART	BART	Going to office	

28	25-45	Other	Union City	Hayward	Car	No traffic in BART	Own Car	Going to office	schedule and price
29	Above 45	Other		Union City	Car	To avoid traffic	BART	While going to SF	Parking
30	25-45	Technology	San Jose	San Jose	Car	While travelling to SF	Own Car	While travelling farther distances	Connectivity
31	18-24	Technology	Mountain View	San Jose	Car	Because it is cheap	Carpool	If I don't want to drive	Slow
32	25-45	Technology	San Mateo	Sunnyvale	No Car	Avoid traffic	Other	When connecting Caltrain to BART	Haven't used much
33	25-45	Technology	San Jose	San Jose	No Car	Avoid traffic	BART	To travel to SF	They are not available 24X7
34	25-45	Technology	San Jose	Fremont	No Car		Carpool	When I have to go to places in cheaper cost and time isn't concern.	Reachability. It's not there in south Silicon Valley (San Jose, Milpitas and Santa Clara).
35	25-45	Construction and Design	Pleasanton	Fremont	No Car	When I don't get a carpool match	Carpool	When don't get a carpool match	Its very costly
36	Above 45	Other	Daly City	South Fremont	Car	Because I don't mind being a little late to my destination	Own Car	When no time constraint	No connectivity to Palo Alto and other tech areas.
37	25-45	Technology	Embarcadero	Castro Valley	Car	I have a straight ride from my home	All	On Mondays and Fridays.Lesser people traffic in trains	Cost
38	25-45	Technology	Oakland	Montgomery	Car		Carpool	When I feel lazy to drive	Maintenance, security
39	25-45	Technology	Union City	South Hayward	No Car	I am not feeling well	Other	When I travel to SF	I don't know
40	25-45	Construction and Design	Embarcadero	Ashby	No Car		BART	Everyday	Cleanliness
41	25-45	Medicine	Glen Park	Castro Valley	No Car		BART	Everyday	Everything
42	25-45	Retail	San Francisco	Oakland	Car	I don't get to drive	Own Car	When I feel tired and don't like driving	Maintenance and reliability
43	25-45	Technology	Pleasanton	South Fremont	Car	I love travelling by public transport	Carpool	When I am not running late on my schedule	Maintenance
44	25-45	Technology	Santa Clara	Hayward	No Car	When I don't get a carpool match	Carpool	When I don't get a match on carpool	Cost
45	18-24	Other	Mountainview	Castro Valley	Car		Carpool	Sometimes	Time and broken vending machines
46	25-45	Construction and Design	Powell Street	Milpitas	Car	Biking from Milpitas to Warm Springs	Own Car/Carpool	Every morning and evening these days	Cost and time
47	25-45	Medicine	Fremont	Fremont	Car	Going to my daughter's place, not to work	Walking	Travelling to Antioch and other places in the Bay Area	Time
48	25-45	Retail	Milbrae	San Jose	Car	I am going to my work place	Own Car/Carpooling	when I go to my father's place in Berkeley	Maintenance

49	25-45	Retail	Dublin	Union City	Car	My car is broke	Carpool	Obvious when my car is broke	The ticket cost is too high
50	25-45	Technology	16th St Mission	West Oakland	Car	There is too much traffic these days	BART	Everytime	Its totally functioning fine
51	25-45	Technology	San Jose	Daly City	Car	I am not going to my office	Bus & Bike	When going to places that are more connected with BART	Not connected to my workplace!
52	25-45	Other	Oakland Airport	Dublin	Car	I don't have to make a lot of transfers	Own Car	Almost always except when I am sick or tired	Too less number of stations
53	18-24	Retail	North Concord	Rockridge	Car	When I am not travelling to my workplace	Carpool	When I am not travelling to my workplace	Frequency and security
54	25-45	Medicine	Hayward	San Bruno	No Car		Carpool	When I feel its okay to be late to work	The time I have to wait in between two transfers
55	18-24	Other	North Berkeley	Bay Fair	Car	To avoid traffic	Carpool	Depends on my mood and the work I have at VCP	Cleanliness
56	25-45	Technology	San Francisco	South Fremont	Car	My husband takes it to his office	Carpool	When I don't get a match on carpool	Cost and delays
57	25-45	Other	San Jose	Fremont	Car		Carpool	When I travel to SF	Connectivity
58	25-45	Technology	Daly City	South Fremont	Car		Own Car	Not very often	No good connectivity
59	Above 45	Technology	Milbrae	San Francisco	Car		BART	I go early and come back early and avoid rush hours	I am pretty big fan of BART
60	18-24	Construction and Design	San Francisco	Milbrae	Car	Construction on roads	BART / Own Car	When there is construction on roads	Frequency
61	25-45	Other	North Berkeley	South Hayward	Car	Due its direct connectivity to my work place	BART	All the time	Cost
62	25-45	Retail	Dublin	Fremont	Car	I have sprain in my ankle	Own Car	When I am not well	Connectivity and Frequency
63	25-45	Retail	San Francisco	Daly City	Car	No particular reason	Own Car	When I feel I am late and would not have parking lot	Time of travel
64	25-45	Technology	San Francisco	San Jose	Car	No traffic in BART	Own Car	When I am not in a rush	Maintenance and reliability
65	25-45	Medicine	Fremont	Pleasanton	Car	No reason	Carpool / Own Car	When I don't get a match on carpool	Connectivity
66	18-24	construction	Warm Springs	Pleasanton	No Car		Carpool	No match by carpool	
67	25-45	Technology	Milpitas	Santa Clara	Car		Own Car	When I travel to SF	Connectivity and stations
68	25-45	Technology	Daly City	San Jose	Car	No traffic in BART	Own Car	Whenever possible	No connectivity to Palo Alto and other tech areas.
69	25-45	Technology	Fremont	Union City	Car	Going to visit a friend	Own Car	When I go far away	Too much time in between transfers
70	25-45	Medicine	Fremont	Walnut Creek	No Car	I like public transit	Carpool	Very often	Cost of the tickets
71	25-45	Technology	Union City	Bay Fair	Car	My Car is repaired	BART		The platforms are

									windy and cold
72	18-24	Other	Hayward	Pleasanton	Car	No traffic in BART	Carpool	No carpool match	Cost of the tickets
73	25-45	Technology	San Bruno	Embarcadero	Car	I am not feeling well	Own Car	Sickness	Maintenance and security
74	25-45	Technology	San Leandro	Downtown Berkeley	Car	Road under construction	Own Car	Road construction or rainy days	I am okay with whatever BART is
75	18-24	Other	South Hayward	West Oakland	No Car	Traffic day today	Carpool	No match by carpool	Security
76	18-24	Construction and Design	Coliseum	Montgomery	Car		Own Car	Whenever I am ok being late	Officials are very rude
77	25-45	Technology	Hayward	Fruitvale	Car	No traffic in BART	Own Car		No proper parking spaces near them
78	25-45	Technology	Fremont	Rockridge	Car	I am not feeling well	Own Car		Cost and maintenance

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